



US009116632B2

(12) **United States Patent**  
**Hara et al.**

(10) **Patent No.:** **US 9,116,632 B2**  
(45) **Date of Patent:** **Aug. 25, 2015**

(54) **STORAGE MANAGEMENT SYSTEM**

(56) **References Cited**

(71) Applicant: **Hitachi, Ltd.**, Tokyo (JP)

U.S. PATENT DOCUMENTS

(72) Inventors: **Junichi Hara**, Tokyo (JP); **Takuya Okamoto**, Tokyo (JP); **Takato Kusama**, Tokyo (JP)

7,395,396	B2 *	7/2008	Takahashi et al.	711/165
7,590,671	B2 *	9/2009	Achiwa	707/822
2007/0055715	A1 *	3/2007	Achiwa	707/204
2008/0082748	A1	4/2008	Liu et al.	
2010/0061184	A1 *	3/2010	Winbow	367/73
2011/0246740	A1 *	10/2011	Yata et al.	711/165
2012/0011336	A1 *	1/2012	Saika	711/162
2012/0311260	A1	12/2012	Yamagiwa et al.	
2014/0143514	A1 *	5/2014	Kulkarni et al.	711/162

(73) Assignee: **HITACHI, LTD.**, Tokyo (JP)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **14/374,431**

JP	2011-221660	A	4/2011
WO	2012/164714	A1	12/2012

(22) PCT Filed: **Dec. 10, 2013**

OTHER PUBLICATIONS

(86) PCT No.: **PCT/JP2013/083080**

International Search Report and Written Opinion, International application No. PCT/JP2013/083080, dated Feb. 25, 2014.

§ 371 (c)(1),

(2) Date: **Jul. 24, 2014**

\* cited by examiner

(65) **Prior Publication Data**

US 2015/0160885 A1 Jun. 11, 2015

*Primary Examiner* — Hyun Nam

(74) *Attorney, Agent, or Firm* — Volpe and Koenig, P.C.

(51) **Int. Cl.**

**G06F 3/00** (2006.01)

**G06F 12/00** (2006.01)

**G06F 3/06** (2006.01)

**H04L 29/12** (2006.01)

**H04L 29/06** (2006.01)

(52) **U.S. Cl.**

CPC ..... **G06F 3/0647** (2013.01); **G06F 3/0608** (2013.01); **G06F 3/0683** (2013.01); **H04L 61/10** (2013.01); **H04L 65/601** (2013.01)

(58) **Field of Classification Search**

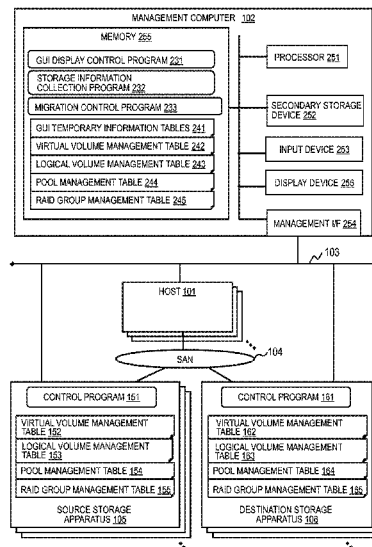
CPC ..... H04L 61/10; H04L 65/601

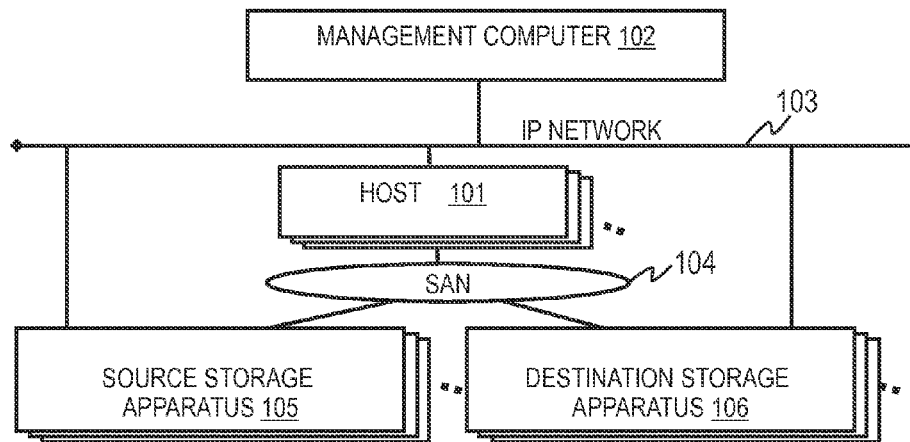
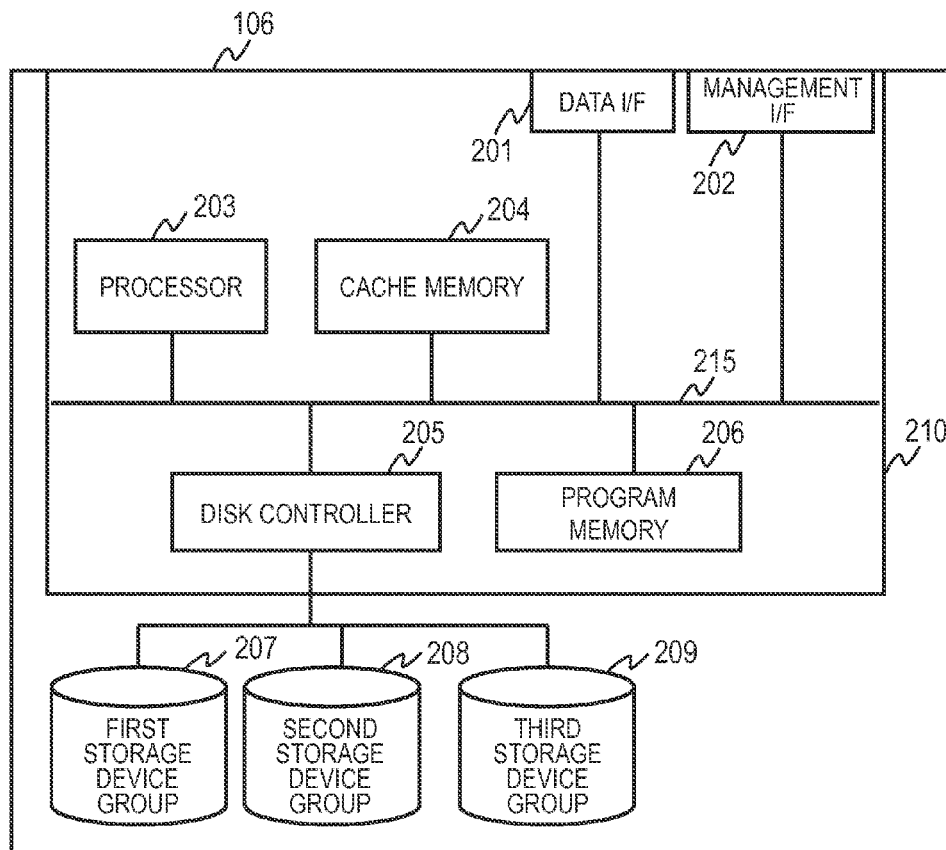
See application file for complete search history.

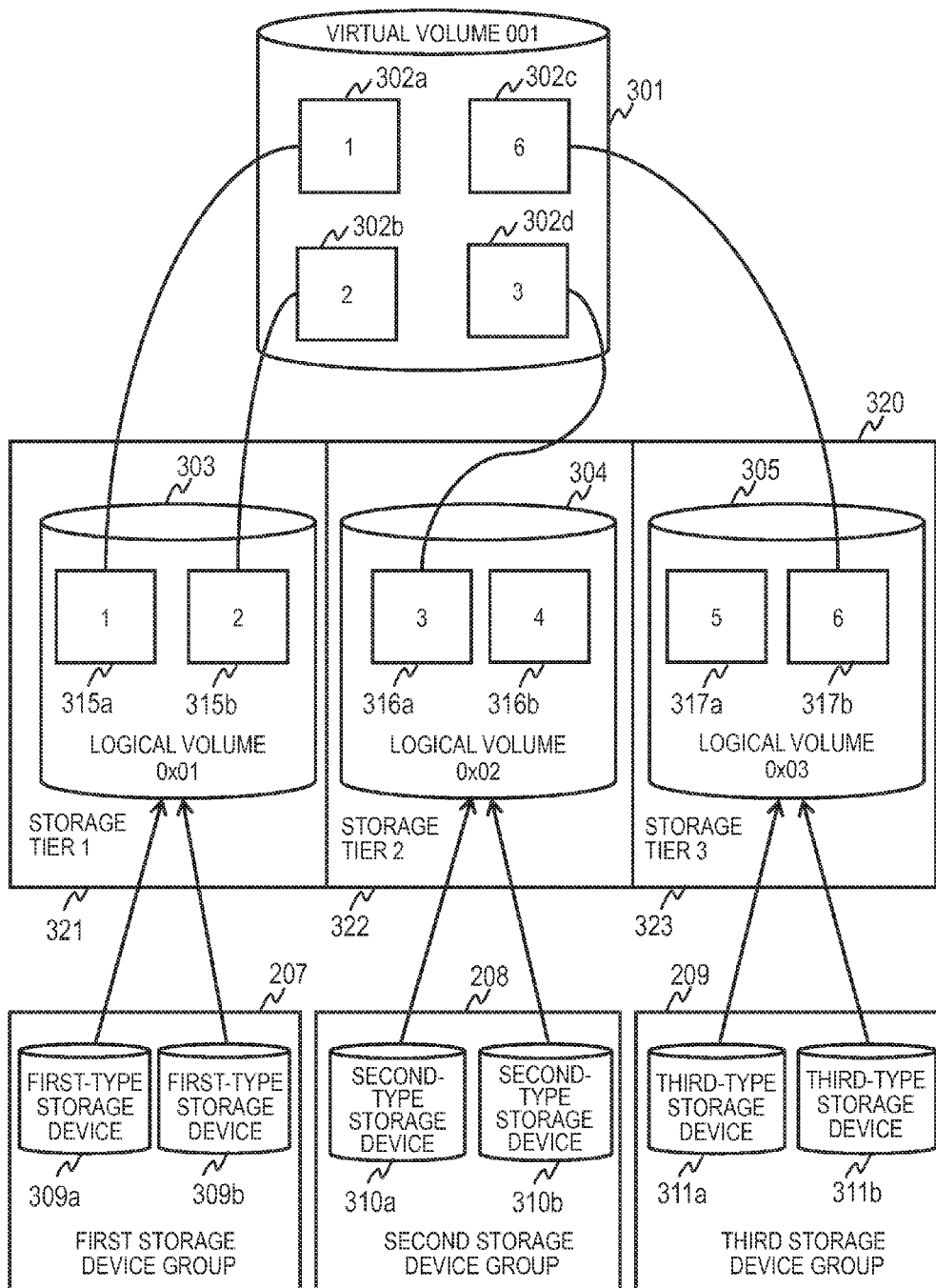
(57) **ABSTRACT**

The storage management system supports planning of volume migration between different storage apparatuses. The storage management system determines source volume groups to which the source volumes belong, determines sizes of volumes to be allocated from the storage device groups to the destination pools, determines sizes of volumes to be migrated from the source volume groups to the destination pools, creates image data indicating information on the determined sizes of volumes to be allocated and the sizes of volumes to be migrated, and outputs the image data to a display device.

**11 Claims, 23 Drawing Sheets**



*Fig. 1**Fig. 2*

*Fig. 3*

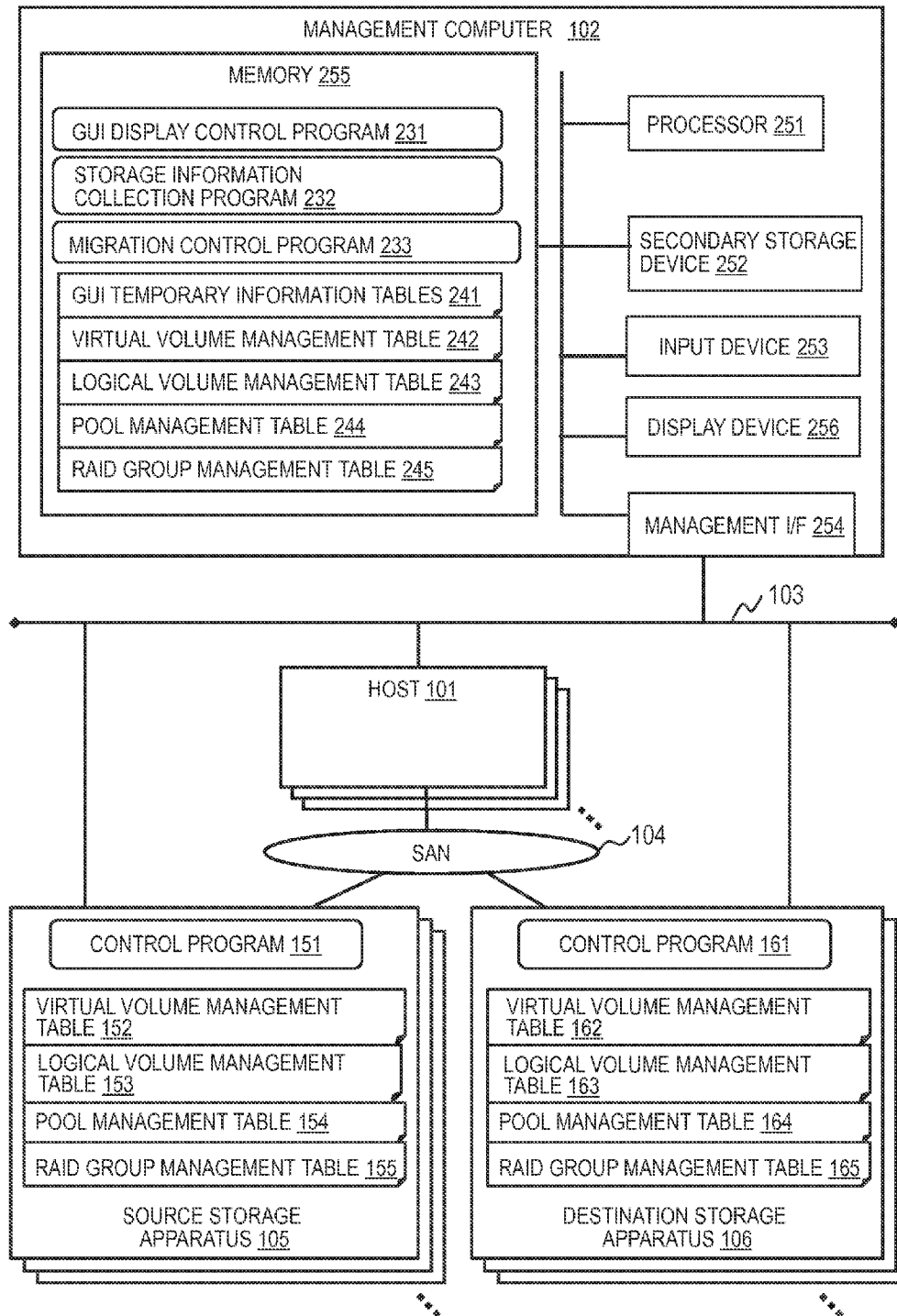


Fig. 4

RAID GROUP MANAGEMENT TABLE <u>245</u>							
STORAGE APPARATUS ID	RAID GROUP ID	RAID GROUP CAPACITY [GB]	RAID GROUP PERFORMANCE [IOPS/GB]	RAID TYPE	STORAGE MEDIA TYPE	STORAGE DEVICE PERFORMANCE [IOPS/GB]	STORAGE DEVICE ID
Str_A	RG_0	100	50K	RAID5	SSD(SLC)	50K	Dev_0
							Dev_1
							Dev_2
	RG_1	200	20K	RAID1	SSD(MLC)	20K	Dev_3
							Dev_4
	:	:	:	:	:	:	:
Str_B	RG_0	500	10K	RAID5	HDD(SAS)	10K	Dev_0
							Dev_1
							Dev_2
	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:

Fig. 5

LOGICAL VOLUME MANAGEMENT TABLE <u>243</u>						
STORAGE APPARATUS ID	LOGICAL VOLUME ID	LOGICAL VOLUME CAPACITY [GB]	LOGICAL VOLUME PERFORMANCE [IOPS/GB]	ASSIGNED HOST	ASSIGNED POOL	RAID GROUP ID
Str_A	LVol_0	10	50K	Host_Y	-	RG_0
	LVol_1	10	20K	-	Pool_0	RG_0
	LVol_2	20	10K	-	-	RG_0
	:	:	:	:	:	:
Str_B	LVol_0	10	10K	-	-	RG_2
	LVol_1	20	20K	-	-	RG_2
	:	:	:	:	:	:
:	:	:	:	:	:	:

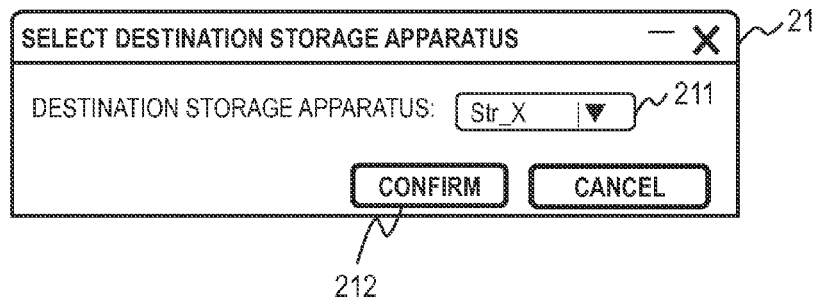
Fig. 6

POOL MANAGEMENT TABLE <u>244</u>				
STORAGE APPARATUS ID	POOL ID	POOL CAPACITY [GB]	POOL PERFORMANCE [IOPS/GB]	LOGICAL VOLUME ID
Str_A	Pool_0	200	15K	LVol_0
				LVol_3
				LVol_6
	Pool_1	300	10K	LVol_1
				LVol_5
	:	:	:	:
Str_B	Pool_0	100	7K	LVol_0
				LVol_1
	:	:	:	:
:	:	:	:	:

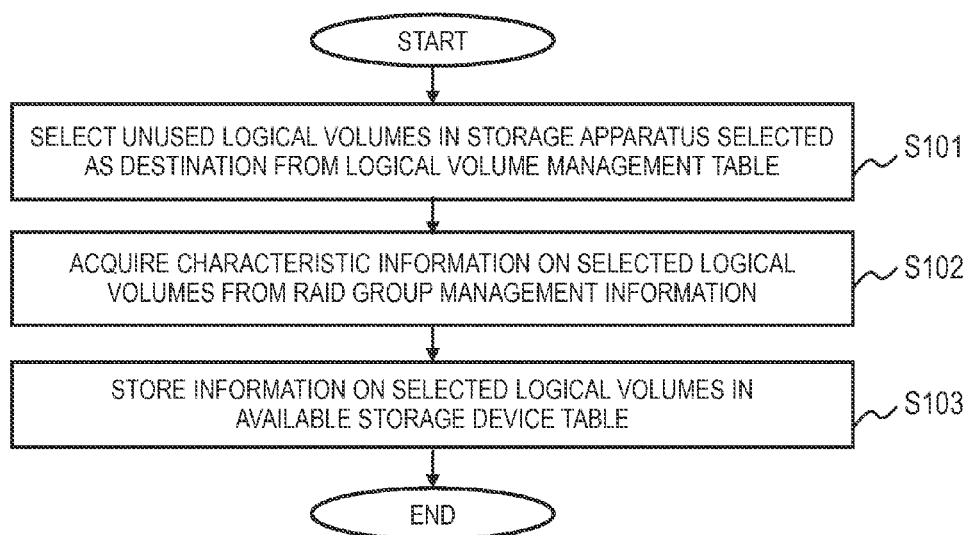
Fig. 7

VIRTUAL VOLUME MANAGEMENT TABLE <u>242</u>						
STORAGE APPARATUS ID	VIRTUAL VOLUME ID	VIRTUAL VOLUME MAXIMUM SIZE [GB]	VIRTUAL VOLUME ACTUAL SIZE IN USE [GB]	VIRTUAL VOLUME PERFORMANCE [IOPS/GB]	ASSIGNED HOST	POOL ID
Str_A	VVol_0	20	10	20K	Host_A	Pool_0
	VVol_1	100	40	20K	-	Pool_1
	:	:	:	:	:	:
Str_B	VVol_0	200	10	30K	Host_C	Pool_0
	VVol_1	100	50	20K	Host_D	Pool_1
	:	:	:	:	:	:
:	:	:	:	:	:	:

Fig. 8

*Fig. 9*

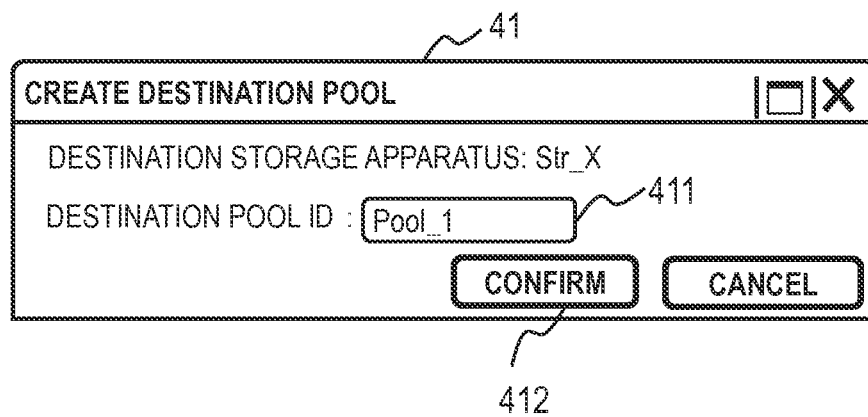
AVAILABLE STORAGE DEVICE TABLE 247				
STORAGE APPARATUS ID	LOGICAL VOLUME ID	LOGICAL VOLUME CAPACITY [GB]	LOGICAL VOLUME PERFORMANCE [IOPS/GB]	STORAGE MEDIA TYPE
Str_X	LVol_0	60	50K	SSD(SLC)
	LVol_1	10	50K	SSD(SLC)
	LVol_2	10	50K	SSD(SLC)
	:	:	:	:

*Fig. 10**Fig. 11*

VOLUME MIGRATION		SOURCE VOLUME 352		DESTINATION (Str_X) POOL 353	
VOLUME DESTINATION CONFIGURATION	<input type="button" value="STORAGE ▼"/>	FILTER	IOPS/GB	DESTINATION UNDETERMINED VOLUMES	(UNCREATED)
USED POOL SPACE [GB]					
STORAGE DEVICE ALLOCATION	DESTINATION (Str_X) STORAGE DEVICE 355		DESTINATION (Str_X) POOL 356		
	STORAGE MEDIA TYPE	IOPS/GB	UNALLOCATED VOLUMES		
	SSD (SLC)	50K	<input type="text" value="110"/>		
	SSD (MLC)	20K	<input type="text" value="500"/>		
	HDD (SAS)	10K	<input type="text" value="3600"/>		
POOL PERFORMANCE [IOPS/GB]					
-					
POOL CAPACITY [GB]					
-					
UNUSED POOL SPACE [GB]					
-					
VOLUME PERFORMANCE <input type="checkbox"/> INCREASE (50% OR MORE) <input checked="" type="checkbox"/> INCREASE (20% OR MORE AND LESS THAN 50%) <input type="checkbox"/> INCREASE/DECREASE (LESS THAN 20%) <input type="checkbox"/> DECREASE (20% OR MORE) <input type="button" value="CREATE DESTINATION POOL"/> <input type="button" value="ADD SOURCE VOLUME"/> <input type="button" value="CHANGE INCREASE/DECREASE INDICATION"/> <input type="button" value="EXECUTE IGRATION"/>					

Fig. 12



*Fig. 13*

35

357

353

356

361

355

354

373

372

374

380

371

370

369

368

367

366

365

364

363

362

361

360

359

358

357

356

355

354

353

352

351

350

349

348

347

346

345

344

343

342

341

340

339

338

337

336

335

334

333

332

331

330

329

328

327

326

325

324

323

322

321

320

319

318

317

316

315

314

313

312

311

310

309

308

307

306

305

304

303

302

301

300

299

298

297

296

295

294

293

292

291

290

289

288

287

286

285

284

283

282

281

280

279

278

277

276

275

274

273

272

271

270

269

268

267

266

265

264

263

262

261

260

259

258

257

256

255

254

253

252

251

250

249

248

247

246

245

244

243

242

241

240

239

238

237

236

235

234

233

232

231

230

229

228

227

226

225

224

223

222

221

220

219

218

217

216

215

214

213

212

211

210

209

208

207

206

205

204

203

202

201

200

199

198

197

196

195

194

193

192

191

190

189

188

187

186

185

184

183

182

181

180

179

178

177

176

175

174

173

172

171

170

169

168

167

166

165

164

163

162

161

160

159

158

157

156

155

154

153

152

151

150

149

148

147

146

145

144

143

142

141

140

139

138

137

136

135

134

133

132

131

130

129

128

127

126

125

124

123

122

121

120

119

118

117

116

115

114

113

112

111

110

109

108

107

106

105

104

103

102

101

100

99

98

97

96

95

94

93

92

91

90

89

88

87

86

85

84

83

82

81

80

79

78

77

76

75

74

73

72

71

70

69

68

67

66

65

64

63

62

61

60

59

58

57

56

55

54

53

52

51

50

49

48

47

46

45

44

43

42

41

40

39

38

37

36

35

34

33

32

31

30

29

28

27

26

25

24

23

22

21

20

19

18

17

16

15

14

13

12

11

10

9

8

7

6

5

4

3

2

1

0

-1

-2

-3

-4

-5

-6

-7

-8

-9

-10

-11

-12

-13

-14

-15

-16

-17

-18

-19

-20

-21

-22

-23

-24

-25

-26

-27

-28

-29

-30

-31

-32

-33

-34

-35

-36

-37

-38

-39

-40

-41

-42

-43

-44

-45

-46

-47

-48

-49

-50

-51

-52

-53

-54

-55

-56

-57

-58

-59

-60

-61

-62

-63

-64

-65

-66

-67

-68

-69

-70

-71

-72

-73

-74

-75

-76

-77

-78

-79

-80

-81

-82

-83

-84

-85

-86

-87

-88

-89

-90

-91

-92

-93

-94

-95

-96

-97

-98

-99

-100

-101

-102

-103

-104

-105

-106

-107

-108

-109

-110

-111

-112

-113

-114

-115

-116

-117

-118

-119

-120

-121

-122

-123

-124

-125

-126

-127

-128

-129

-130

-131

-132

-133

-134

-135

-136

-137

-138

-139

-140

-141

-142

-143

-144

-145

-146

-147

-148

-149

-150

-151

-152

-153

-154

-155

-156

-157

-158

-159

-160

-161

-162

-163

-164

-165

-166

-167

-168

-169

-170

-171

-172

-173

-174

-175

-176

-177

-178

-179

-180

-181

-182

-183

-184

-185

-186

-187

-188

-189

-190

-191

-192

-193

-194

-195

-196

-197

-198

-199

-200

-201

-202

-203

-204

-205

-206

-207

-208

-209

-210

-211

-212

-213

-214

-215

-216

-217

-218

-219

-220

-221

-222

-223

-224

-225

-226

-227

-228

-229

-230

-231

-232

-233

-234

-235

-236

-237

-238

-239

-240

-241

-242

-243

-244

-245

-246

-247

-248

-249

-250

-251

-252

-253

-254

-255

-256

-257

-258

-259

-260

-261

-262

-263

-264

-265

-266

-267

-268

-269

-270

-271

-272

-273

-274

-275

-276

-277

-278

-279

-280

-281

-282

-283

-284

-285

-286

-287

-288

-289

-290

-291

-292

-293

-294

-295

-296

-297

-298

-299

-300

-301

-302

-303

-304

-305

-306

-307

-308

-309

-310

-311

-312

-313

-314

-315

-316

-317

-318

-319

-320

-321

-322

-323

-324

-325

-326

-327

-328

-329

-330

-331

-332

-333

-334

-335

-336

-337

-338

-339

-340

-341

-342

-343

-344

-345

-346

-347

-348

-349

-350

-351

-352

-353

-354

-355

-356

-357

-358

-359

-360

-361

-362

-363

-364

-365

-366

-367

-368

-369

-370

-371

-372

-373

-374

-375

-376

-377

-378

-379

-380

-381

-382

-383

-384

-385

-386

-387

-388

-389

-390

-391

-392

-393

-394

-395

-396

-397

-398

-399

-400

-401

-402

-403

-404

-405

-406

-407

-408

-409

-410

-411

-412

-413

-414

-415

-416

-417

51

SELECT LOGICAL VOLUME TO ALLOCATE| □ | X

DESTINATION STORAGE APPARATUS: Str\_X

<input type="checkbox"/>	LOGICAL VOLUME	STORAGE MEDIA TYPE	IOPS/GB	CAPACITY [GB]
<input checked="" type="checkbox"/>	LVol_0	SSD(SLC)	50000	60
<input type="checkbox"/>	LVol_1	SSD(SLC)	50000	10
<input type="checkbox"/>	LVol_2	SSD(SLC)	50000	10
<input type="checkbox"/>	LVol_3	SSD(SLC)	50000	10
<input type="checkbox"/>	LVol_4	SSD(SLC)	50000	20

511

TOTAL VOLUME SIZE TO BE ADDED: 60 [GB]

CONFIRMCANCEL

512

Fig. 15

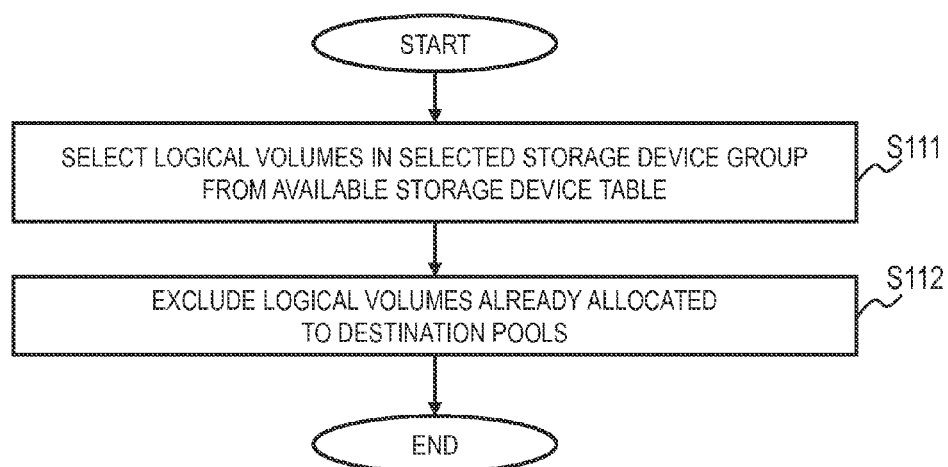
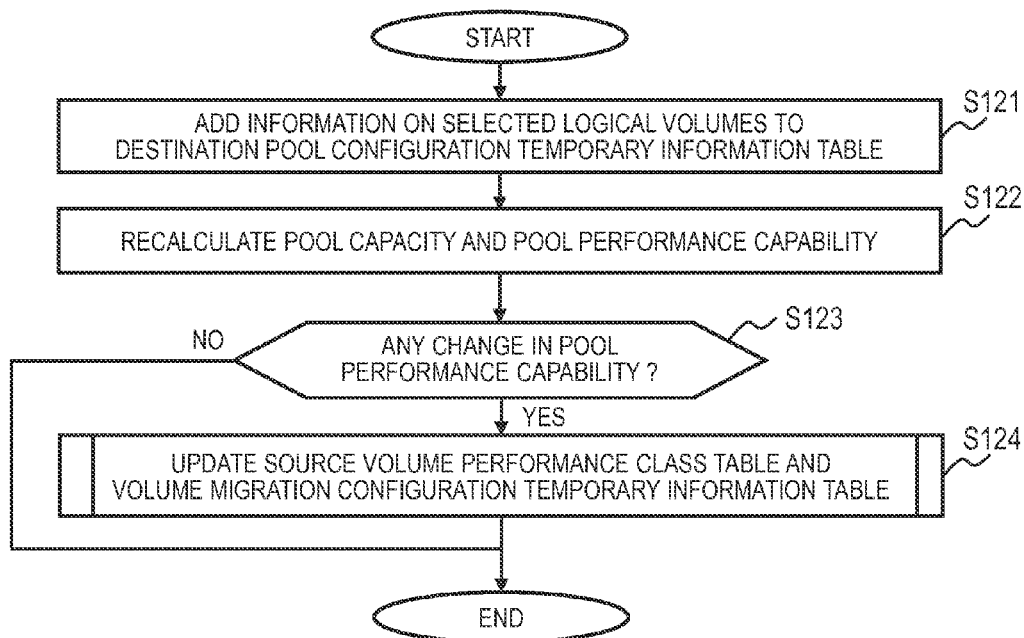
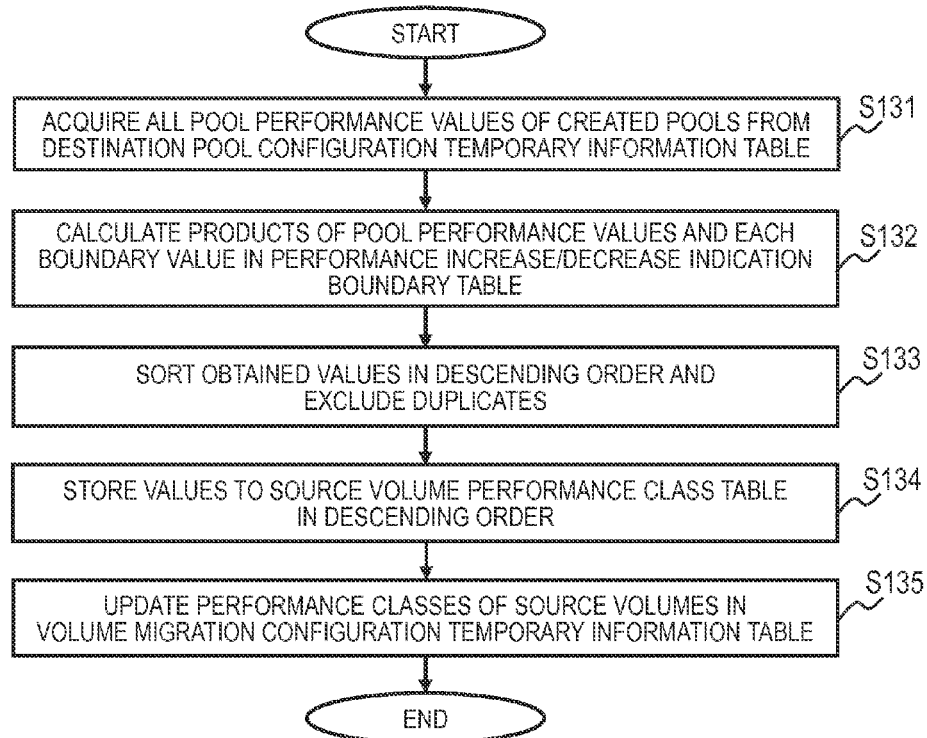


Fig. 16

DESTINATION POOL CONFIGURATION TEMPORARY INFORMATION TABLE 248							
STORAGE APPARATUS ID	POOL ID	POOL CAPACITY [GB]	POOL PERFORMANCE [IOPS/GB]	LOGICAL VOLUME ID	LOGICAL VOLUME CAPACITY [GB]	LOGICAL VOLUME PERFORMANCE [IOPS/GB]	STORAGE MEDIA TYPE
Str_X	Pool_1	260	27K	LVol_0	60	50K	SSD(SLC)
				LVol_5	100	20K	SSD(MLC)
				LVol_6	100	20K	SSD(MLC)
	Pool_2	800	14K	LVol_7	300	20K	SSD(MLC)
				LVol_8	500	10K	HDD(SAS)
	Pool_3	1100	10K	LVol_9	1100	10K	HDD(SAS)

Fig. 17

*Fig. 18**Fig. 19*

SOURCE VOLUME PERFORMANCE CLASS TABLE 246		
PERFORMANCE CLASS ID	HIGHEST PERFORMANCE [IOPS/GB]	LOWEST PERFORMANCE [IOPS/GB]
Perf_0	-	41K
Perf_1	41K	33K
Perf_2	33K	22K
Perf_3	22K	21K
Perf_4	17K	15K
Perf_5	15K	12K
Perf_6	12K	11K
Perf_7	11K	8K
Perf_8	8K	0K

*Fig. 20*

PERFORMANCE INCREASE/DECREASE INDICATION BOUNDARY TABLE 292	
BOUNDARY VALUE [%]	
	+50
	+20
	-20

*Fig. 21*

~ 73

CHANGE INCREASE/DECREASE INDICATION

INCREASE

50% OR MORE50% OR MORE

INCREASE

20% OR MORE AND LESS THAN 50%

INCREASE/DECREASE

LESS THAN 20%

DECREASE

20% OR MORE

CONFIRM

CANCEL

*Fig. 22*

35

357

380

374

373

372

371

354

351

353

356

355

352

350

349

348

347

346

345

344

343

342

341

340

339

338

337

336

335

334

333

332

331

330

329

328

327

326

325

324

323

322

321

320

319

318

317

316

315

314

313

312

311

310

309

308

307

306

305

304

303

302

301

300

299

298

297

296

295

294

293

292

291

290

289

288

287

286

285

284

283

282

281

280

279

278

277

276

275

274

273

272

271

270

269

268

267

266

265

264

263

262

261

260

259

258

257

256

255

254

253

252

251

250

249

248

247

246

245

244

243

242

241

240

239

238

237

236

235

234

233

232

231

230

229

228

227

226

225

224

223

222

221

220

219

218

217

216

215

214

213

212

211

210

209

208

207

206

205

204

203

202

201

200

199

198

197

196

195

194

193

192

191

190

189

188

187

186

185

184

183

182

181

180

179

178

177

176

175

174

173

172

171

170

169

168

167

166

165

164

163

162

161

160

159

158

157

156

155

154

153

152

151

150

149

148

147

146

145

144

143

142

141

140

139

138

137

136

135

134

133

132

131

130

129

128

127

126

125

124

123

122

121

120

119

118

117

116

115

114

113

112

111

110

109

108

107

106

105

104

103

102

101

100

99

98

97

96

95

94

93

92

91

90

89

88

87

86

85

84

83

82

81

80

79

78

77

76

75

74

73

72

71

70

69

68

67

66

65

64

63

62

61

60

59

58

57

56

55

54

53

52

51

50

49

48

47

46

45

44

43

42

41

40

39

38

37

36

35

34

33

32

31

30

29

28

27

26

25

24

23

22

21

20

19

18

17

16

15

14

13

12

11

10

9

8

7

6

5

4

3

2

1

0

-1

-2

-3

-4

-5

-6

-7

-8

-9

-10

-11

-12

-13

-14

-15

-16

-17

-18

-19

-20

-21

-22

-23

-24

-25

-26

-27

-28

-29

-30

-31

-32

-33

-34

-35

-36

-37

-38

-39

-40

-41

-42

-43

-44

-45

-46

-47

-48

-49

-50

-51

-52

-53

-54

-55

-56

-57

-58

-59

-60

-61

-62

-63

-64

-65

-66

-67

-68

-69

-70

-71

-72

-73

-74

-75

-76

-77

-78

-79

-80

-81

-82

-83

-84

-85

-86

-87

-88

-89

-90

-91

-92

-93

-94

-95

-96

-97

-98

-99

-100

-101

-102

-103

-104

-105

-106

-107

-108

-109

-110

-111

-112

-113

-114

-115

-116

-117

-118

-119

-120

-121

-122

-123

-124

-125

-126

-127

-128

-129

-130

-131

-132

-133

-134

-135

-136

-137

-138

-139

-140

-141

-142

-143

-144

-145

-146

-147

-148

-149

-150

-151

-152

-153

-154

-155

-156

-157

-158

-159

-160

-161

-162

-163

-164

-165

-166

-167

-168

-169

-170

-171

-172

-173

-174

-175

-176

-177

-178

-179

-180

-181

-182

-183

-184

-185

-186

-187

-188

-189

-190

-191

-192

-193

-194

-195

-196

-197

-198

-199

-200

-201

-202

-203

-204

-205

-206

-207

-208

-209

-210

-211

-212

-213

-214

-215

-216

-217

-218

-219

-220

-221

-222

-223

-224

-225

-226

-227

-228

-229

-230

-231

-232

-233

-234

-235

-236

-237

-238

-239

-240

-241

-242

-243

-244

-245

-246

-247

-248

-249

-250

-251

-252

-253

-254

-255

-256

-257

-258

-259

-260

-261

-262

-263

-264

-265

-266

-267

-268

-269

-270

-271

-272

-273

-274

-275

-276

-277

-278

-279

-280

-281

-282

-283

-284

-285

-286

-287

-288

-289

-290

-291

-292

-293

-294

-295

-296

-297

-298

-299

-300

-301

-302

-303

-304

-305

-306

-307

-308

-309

-310

-311

-312

-313

-314

-315

-316

-317

-318

-319

-320

-321

-322

-323

-324

-325

-326

-327

-328

-329

-330

-331

-332

-333

-334

-335

-336

-337

-338

-339

-340

-341

-342

-343

-344

-345

-346

-347

-348

-349

-350

-351

-352

-353

-354

-355

-356

-357

-358

-359

-360

-361

-362

-363

-364

-365

-366

-367

-368

-369

-370

-371

-372

-373

-374

-375

-376

-377

-378

-379

-380

-381

-382

-383

-384

-385

-386

-387

-388

-389

-390

-391

-392

-393

-394

-395

-396

-397

-398

-399

-400

-401

-402

-403

-404

-405

-406

-407

-408

-409

-410

-411

-412

-413

-414

-415

-416

-417

-418

-419

-420

-421

-422

-423

-424

-425

-426

-427

-428

-429

-430

-431

-432

-433

-434

-435

**ADD SOURCE VOLUME** | □ | X

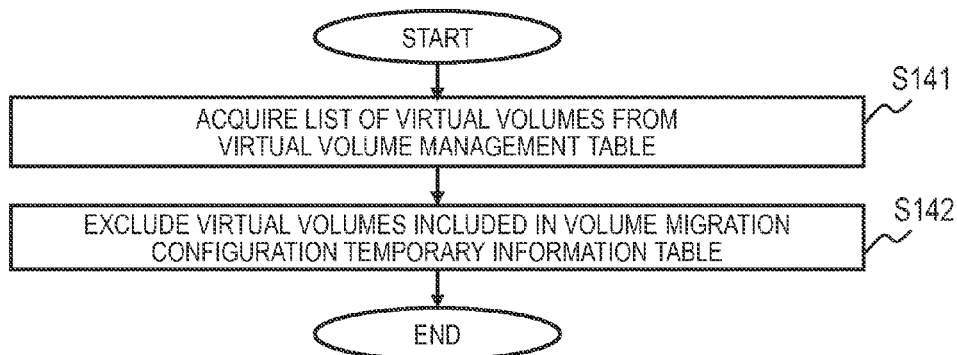
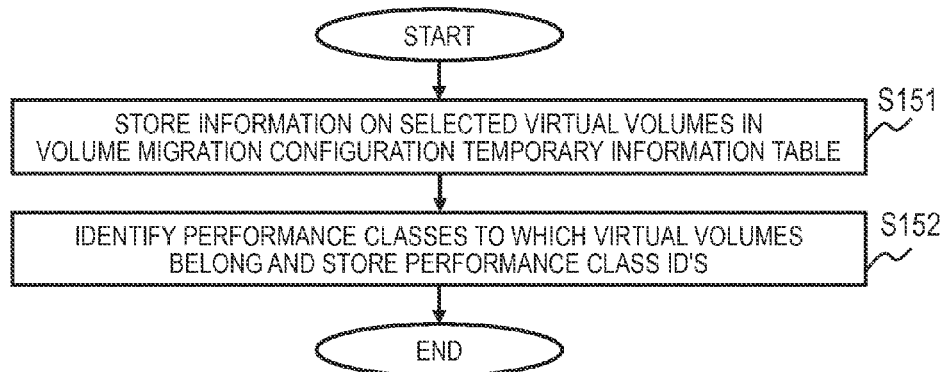
SOURCE STORAGE APPARATUS : Str\_A ▼

□	VIRTUAL VOLUME	IOPS/GB	MAXIMUM SIZE	ACTUAL SIZE IN USE	ASSIGNED HOST
☑	VVol_1	20000	10	5	Host_B
☑	VVol_2	20000	20	10	Host_B
☑	VVol_3	20000	20	15	Host_C
□	VVol_4	20000	10	5	Host_C
□	VVol_5	20000	50	40	Host_D
□	VVol_6	20000	40	30	Host_D

72

721

CONFIRM
CANCEL

*Fig. 24**Fig. 25**Fig. 26*



VOLUME MIGRATION CONFIGURATION TEMPORARY INFORMATION TABLE 249										
SOURCE VOLUME							DESTINATION POOL			
STORAGE APPARATUS ID	VIRTUAL VOLUME ID	VIRTUAL VOLUME MAXIMUM SIZE [GB]	VIRTUAL VOLUME ACTUAL SIZE IN USE [GB]	VIRTUAL VOLUME PERFORMANCE [IOPS/GB]	ASSIGNED HOST	PERFORMANCE CLASS ID	STORAGE APPARATUS ID	POOL ID	POOL PERFORMANCE [IOPS/GB]	ESTIMATED PERFORMANCE INCREASE/DECREASE
Str_A	VVol_0	20	10	30K	Host_A	Perf_2	Str_X	-	-	-
	VVol_1	20	20	30K	Host_B	Perf_2		-	-	-
	VVol_2	30	20	30K	Host_C	Perf_2		-	-	-
	:	:	:	:	:	:		:	:	:
	:	:	:	:	:	:		:	:	:

Fig. 27

VOLUME MIGRATION

351

VOLUME  
DESTINATION  
CONFIGURATION

352

SOURCE VOLUME

STORAGE	FILTER	IOPS/GB	DESTINATION UNDETERMINED VOLUMES
Str_A		22K - 33K	50
		15K - 17K	400
		15K - 17K	500
Str_B		11K - 12K	300
		0K - 8K	1400

353

DESTINATION (Str X) POOL

Pool_1	Pool_2	Pool_3
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

357

0

354

STORAGE  
DEVICE  
ALLOCATION

355

DESTINATION (Str X) STORAGE DEVICE

STORAGE MEDIA TYPE	IOPS/GB	UNALLOCATED VOLUMES
SSD (SLC)	50K	50
SSD (MLC)	20K	200
HDD (SAS)	10K	2000

356

DESTINATION (Str X) POOL

Pool_1	Pool_2	Pool_3
50	0	0
200	300	0
0	500	1100

358

0

359

VOLUME PERFORMANCE  
INCREASE/DECREASE:

360

POOL PERFORMANCE [IOPS/GB]

POOL CAPACITY [GB]	POOL PERFORMANCE [IOPS/GB]
27K	14K
260	800
260	800

361

UNUSED POOL SPACE [GB]

UNUSED POOL SPACE [GB]
1100

362

CREATE DESTINATION POOL

363

ADD SOURCE VOLUME

364

CHANGE INCREASE/DECREASE INDICATION

365

INCREASE (50% OR MORE)

366

INCREASE (20% OR MORE AND LESS THAN 50%)

367

INCREASE/DECREASE (LESS THAN 20%)

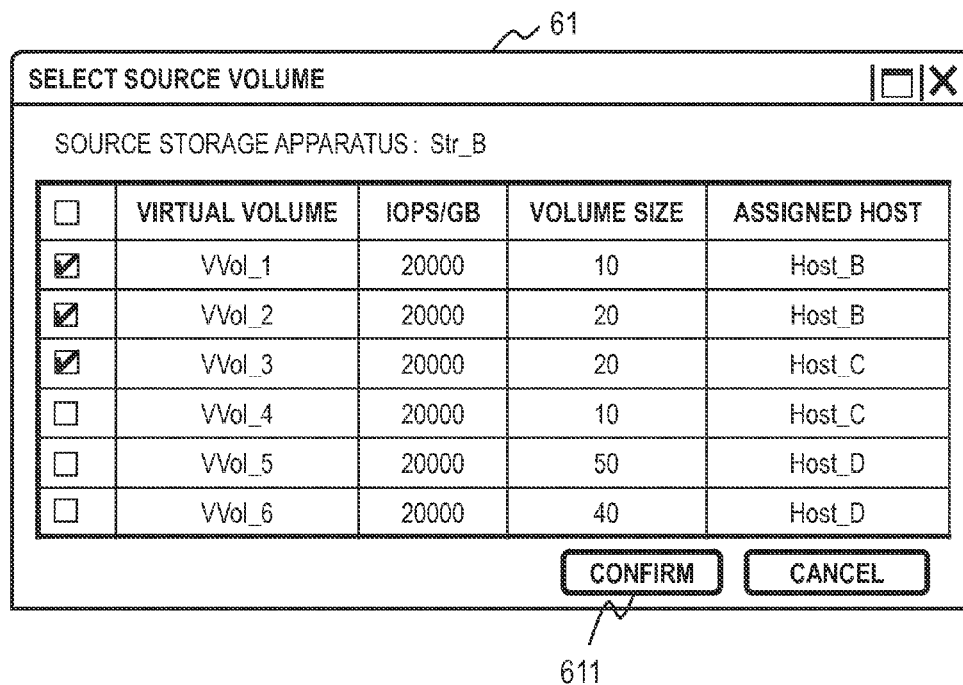
368

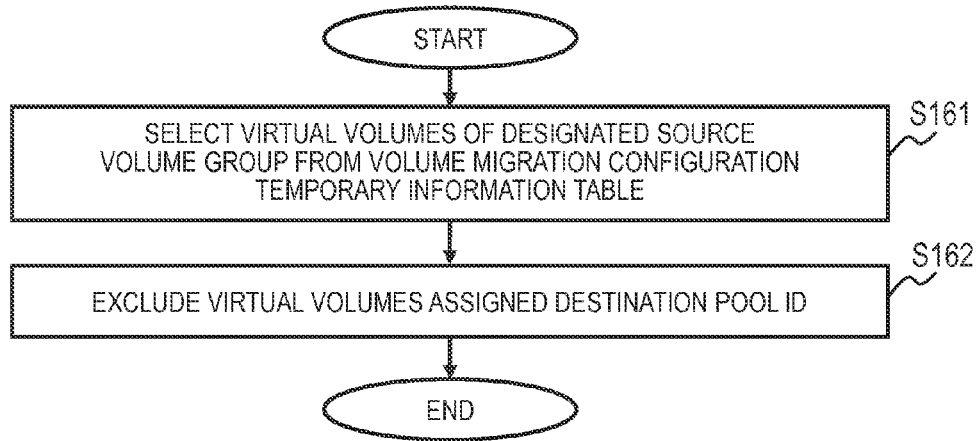
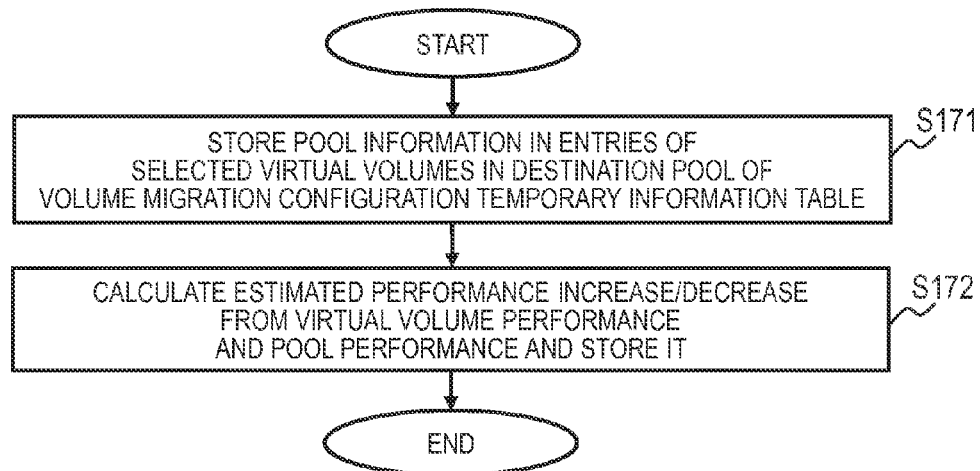
DECREASE (20% OR MORE)

369

EXECUTE MIGRATION

Fig. 28

*Fig. 29*

*Fig. 30**Fig. 31*

VOLUME MIGRATION CONFIGURATION TEMPORARY INFORMATION TABLE 249										
SOURCE VOLUME							DESTINATION POOL			
STORAGE APPARATUS ID	VIRTUAL VOLUME ID	VIRTUAL VOLUME MAXIMUM SIZE [GB]	VIRTUAL VOLUME ACTUAL SIZE IN USE [GB]	VIRTUAL VOLUME PERFORMANCE [IOPS/GB]	ASSIGNED HOST	PERFORMANCE CLASS ID	STORAGE APPARATUS ID	POOL ID	POOL PERFORMANCE [IOPS/GB]	ESTIMATED PERFORMANCE INCREASE/DECREASE
Str_A	VVol_0	20	10	30K	Host_A	Perf_2	Str_X	Pool_1	27K	-11%
	VVol_1	20	20	30K	Host_B	Perf_2		Pool_1	27K	-11%
	VVol_2	30	20	30K	Host_C	Perf_2		Pool_1	27K	-11%
	:	:	:	:	:	:		:	:	:

Fig. 32

35

357

351

354

380

371

372

373

374

**VOLUME MIGRATION**

**VOLUME DESTINATION CONFIGURATION**

SOURCE VOLUME 352		DESTINATION (Str X) POOL 353	
STORAGE   ▼   FILTER	IOPS/GB	Pool_1	Pool_2
Str_A	22K - 33K	50	0
	15K - 17K	100	200
Str_B	15K - 17K	0	100
	11K - 12K	0	500
Str_C	0K - 8K	0	0
USED POOL SPACE [GB]		150	800
1000		1000	

**VOLUME PERFORMANCE INCREASE/DECREASE:**

**CREATE DESTINATION POOL**

**STORAGE DEVICE ALLOCATION**

DESTINATION (Str X) STORAGE DEVICE 355		DESTINATION (Str X) POOL 356	
STORAGE MEDIA TYPE	IOPS/GB	Pool_1	Pool_2
SSD (SLC)	50K	50	0
SSD (MLC)	20K	200	300
HDD (SAS)	10K	0	500
POOL PERFORMANCE [IOPS/GB]		27K	14K
POOL CAPACITY [GB]		260	800
UNUSED POOL SPACE [GB]		110	200
100		100	

**VOLUME PERFORMANCE INCREASE/DECREASE:**

**CREATE DESTINATION POOL**

**ADD SOURCE VOLUME**

**CHANGE INCREASE/DECREASE INDICATION**

**EXECUTE MIGRATION**

**VOLUME PERFORMANCE INCREASE/DECREASE:**

**INCREASE (50% OR MORE)**

**INCREASE (20% OR MORE AND LESS THAN 50%)**

**INCREASE/DECREASE (LESS THAN 20%)**

**DECREASE (20% OR MORE)**

**EXECUTE MIGRATION**

**Fig. 33**

35

357

351

353

354

355

356

357

358

359

360

361

362

363

364

365

366

367

368

369

370

371

372

373

374

375

376

377

378

379

380

381

382

383

384

385

386

387

388

389

390

391

392

393

394

395

396

397

398

399

400

401

402

403

404

405

406

407

408

409

410

411

412

413

414

415

416

417

418

419

420

421

422

423

424

425

426

427

428

429

430

431

432

433

434

435

436

437

438

439

440

441

442

443

444

445

446

447

448

449

450

451

452

453

454

455

456

457

458

459

460

461

462

463

464

465

466

467

468

469

470

471

472

473

474

475

476

477

478

479

480

481

482

483

484

485

486

487

488

489

490

491

492

493

494

495

496

497

498

499

500

501

502

503

504

505

506

507

508

509

510

511

512

513

514

515

516

517

518

519

520

521

522

523

524

525

526

527

528

529

530

531

532

533

534

535

536

537

538

539

540

541

542

543

544

545

546

547

548

549

550

551

552

553

554

555

556

557

558

559

560

561

562

563

564

565

566

567

568

569

570

571

572

573

574

575

576

577

578

579

580

581

582

583

584

585

586

587

588

589

590

591

592

593

594

595

596

597

598

599

600

601

602

603

604

605

606

607

608

609

610

611

612

613

614

615

616

617

618

619

620

621

622

623

624

625

626

627

628

629

630

631

632

633

634

635

636

637

638

639

640

641

642

643

644

645

646

647

648

649

650

651

652

653

654

655

656

657

658

659

660

661

662

663

664

665

666

667

668

669

670

671

672

673

674

675

676

677

678

679

680

681

682

683

684

685

686

687

688

689

690

691

692

693

694

695

696

697

698

699

700

701

702

703

704

705

706

707

708

709

710

711

712

713

714

715

716

717

718

719

720

721

722

723

724

725

726

727

728

729

730

731

732

733

734

735

736

737

738

739

740

741

742

743

744

745

746

747

748

749

750

751

752

753

754

755

756

757

758

759

760

761

762

763

764

765

766

767

768

769

770

771

772

773

774

775

776

777

778

779

780

781

782

783

784

785

786

787

788

789

790

791

792

793

794

795

796

797

798

799

800

801

802

803

804

805

806

807

808

809

810

811

812

813

814

815

816

817

818

819

820

821

822

823

824

825

826

827

828

829

830

831

832

833

834

835

836

837

838

839

840

841

842

843

844

845

846

847

848

849

850

851

852

853

854

855

856

857

858

859

860

861

862

863

864

865

866

867

868

869

870

871

872

873

874

875

876

877

878

879

880

881

882

883

884

885

886

887

888

889

890

891

892

893

894

895

896

897

898

899

900

901

902

903

904

905

906

907

908

909

910

911

912

913

914

915

916

917

918

919

920

921

922

923

924

925

926

927

928

929

930

931

932

933

934

935

936

937

938

939

940

941

942

943

944

945

946

947

948

949

950

951

952

953

954

955

956

957

958

959

960

961

962

963

964

965

966

967

968

969

970

971

972

973

974

975

976

977

978

979

980

981

982

983

984

985

986

987

988

989

990

991

992

993

994

995

996

997

998

999

1000

1001

1002

1003

1004

1005

1006

1007

1008

1009

1010

1011

1012

1013

1014

1015

1016

1017

1018

1019

1020

1021

1022

1023

1024

1025

1026

1027

1028

1029

1030

1031

1032

1033

1034

1035

1036

1037

1038

1039

1040

1041

1042

1043

1044

1045

1046

1047

1048

1049

1050

1051

1052

1053

1054

1055

1056

1057

1058

1059

1060

1061

1062

1063

1064

1065

1066

1067

1068

1069

1070

1071

1072

1073

1074

1075

1076

1077

1078

1079

1080

1081

1082

1083

1084

1085

1086

1087

1088

1089

1090

1091

1092

1093

1094

1095

1096

1097

1098

1099

1100

1101

1102

1103

1104

1105

1106

1107

1108

1109

1110

1111

1112

1113

1114

1115

1116

1117

1118

1119

1120

1121

1122

1123

1124

1125

1126

1127

1128

1129

1130

1131

1132

1133

1134

1135

1136

1137

1138

1139

1140

1141

1142

1143

1144

1145

1146

1147

1148

1149

1150

1151

1152

1153

1154

1155

1156

1157

1158

1159

1160

1161

1162

1163

1164

1165

1166

1167

1168

1169

1170

1171

1172

1173

1174

1175

1176

1177

1178

1179

1180

1181

1182

1183

1184

1185

1186

1187

1188

1189

1190

1191

1192

1193

1194

1195

1196

1197

1198

1199

1200

1201

1202

1203

1204

1205

1206

1207

1208

1209

1210

1211

1212

1213

1214

1215

1216

1217

1218

1219

1220

1221

1222

1223

1224

1225

1226

1227

1228

1229

1230

1231

1232

1233

1234

1235

1236

1237

1238

1239

1240

1241

1242

1243

1244

1245

1246

1247

1248

1249

1250

1251

1252

1253

1254

1255

1256

1257

1258

1259

1260

1261

1262

1263

1264

1265

1266

1267

1268

1269

1270

1271

1272

1273

1274

1275

1276

1277

1278

1279

1280

1281

1282

1283

1284

1285

1286

1287

1288

1289

1290

1291

1292

1293

1294

1295

1296

1297

1298

1299

1300

1301

1302

1303

1304

1305

1306

1307

1308

1309

1310

1311

1312

1313

1314

1315

1316

1317

1318

1319

1320

1321

1322

1323

1324

1325

1326

1327

1328

1329

1330

1331

1332

1333

1334

1335

1336

1337

1338

1339

1340

1341

1342

1343

1344

1345

1346

1347

1348

1349

1350

1351

1352

1353

1354

1355

1356

1357

1358

1359

1360

1361

1362

1363

1364

1365

1366

1367

1368

1369

1370

1371

1372

1373

1374

1375

1376

1377

1378

1379

1380

1381

1382

1383

1384

1385

1386

1387

1388

1389

1390

1391

1392

1393

1394

1395

1396

1397

1398

1399

1400

1401

1402

1403

1404

1405

1406

1407

1408

1409

1410

1411

1412

1413

1414

1415

1416

1417

1418

1419

1420

1421

1422

1423

1424

1425

1426

1427

1428

1429

1430

1431

1432

1433

1434

1435

1436

1437

1438

1439

1440

1441

1442

1443

1444

1445

1446

1447

1448

1449

1450

1451

1452

1453

1454

1455

1456

1457

1458

1459

1460

1461

1462

1463

1464

1465

1466

1467

1468

1469

1470

1471

1472

1473

1474

1475

1476

1477

1478

1479

1480

1481

1482

1483

1484

1485

1486

1487

1488

1489

1490

1491

1492

1493

1494

1495

1496

1497

1498

1499

1500

1501

1502

1503

1504

1505

1506

1507

1508

1509

1510

1511

1512

1513

1514

1515

1516

1517

1518

1519

1520

1521

1522

1523

1524

1525

1526

1527

1528

1529

1530

1531

1532

1533

1534

1535

1536

1537

1538

1539

1540

1541

1542

1543

1544

1545

1546

1547

1548

1549

1550

1551

1552

1553

1554

1555

1556

1557

1558

1559

1560

1561

1562

1563

1564

1565

1566

1567

1568

1569

1570

1571

1572

1573

1574

1575

1576

1577

1578

1579

1580

1581

1582

1583

1584

1585

1586

1587

1588

1589

1590

1591

1592

1593

1594

1595

1596

1597

1598

1599

1600

1601

1602

1603

1604

1605

1606

1607

1608

1609

1610

1611

1612

1613

1614

1615

1616

1617

1618

1619

1620

1621

1622

1623

1624

1625

1626

1627

1628

1629

1630

1631

1632

1633

1634

Fig. 35



## STORAGE MANAGEMENT SYSTEM

## BACKGROUND

This invention relates to management of volume migration between storage apparatuses.

The background of this application includes Patent Literature 1. The volumes belonging to storage devices A to D are virtually managed as a consolidation. A host recognizes the plurality of storage devices A to D as a single virtual storage device. The user can discretionally group the volumes of the storage system into storage layers 1 to 3. For example, the storage layer 1 may be defined as a highly reliable layer, the storage layer 2 as a low-cost layer, and the storage layer 3 as an archive layer. When the user designates volumes V1 and V2 to be migrated on a group basis together with the destination storage layer, data is relocated.

Patent Literature 1: U.S. Pat. No. 7,395,396

## SUMMARY

In the case of volume migration between different models, for example, from a storage apparatus of an old model to a storage apparatus of a new model, storage media mounted in the source storage apparatus and the destination storage apparatus are different in the type, capacity, and performance capability. Accordingly, the storage administrator newly configures volumes and pools in the destination storage apparatus. The storage administrator should pay attention to the difference in performance capability of the volumes before and after the migration in determining the configuration of the destination storage apparatus.

The volume performance in the destination storage apparatus depends on the performance of the pool in the destination storage apparatus to which the migrated volume belongs. The performance of a pool depends on the sizes of storage areas provided by storage devices and the performance of the storage devices.

Traditional storage management systems, however, perform displaying information on pool configuration in the destination storage apparatus and configuring pools separately from displaying information on destination in volume migration and configuring volume migration. Accordingly, the storage administrator cannot efficiently pursue planning of volume migration that satisfies desired performance requirements.

An aspect of this invention is a storage management system for managing source storage apparatuses including source volumes and a destination storage apparatus to which the source volumes are migrated, the storage management system including a processor and a memory device. The memory device holds: volume management information including information on owner apparatuses and characteristics of the source volumes; destination pool configuration management information including sizes of volumes to be allocated from storage device groups in the destination storage apparatus to destination pools; and volume migration configuration management information including information on relations between the source volumes and the destination pools. The processor determines source volume groups to which the source volumes belong based on the volume management information. The processor determines sizes of volumes to be allocated from the storage device groups to the destination pools based on the destination pool configuration management information. The processor determines sizes of volumes to be migrated from the source volume groups to the destination pools based on the volume migration configuration man-

agement information. The processor creates image data indicating information on the determined sizes of volumes to be allocated and the sizes of volumes to be migrated. The processor outputs the image data to a display device.

An aspect of this invention provides appropriate support to the storage administrator in planning of volume migration between different storage apparatuses.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram schematically illustrating a general configuration of a computer system;

FIG. 2 illustrates an example of hardware configuration of a storage apparatus;

FIG. 3 schematically illustrates an example of logical configuration of volumes a destination storage apparatus provides to a host apparatus and an example of relations among volumes and storage device groups;

FIG. 4 illustrates an example of hardware configuration of a management computer and an example of software configuration of the computer system;

FIG. 5 illustrates a configuration example of a RAID group management table in the management computer;

FIG. 6 illustrates a configuration example of a logical volume management table in the management computer;

FIG. 7 illustrates a configuration example of a pool management table in the management computer;

FIG. 8 illustrates a configuration example of a virtual volume management table in the management computer;

FIG. 9 illustrates an example of a Select Destination Storage Apparatus window to appear first after start-up of a volume migration GUI;

FIG. 10 illustrates a configuration example of an available storage device table in the management computer;

FIG. 11 is a flowchart illustrating processing to create or update the available storage device table;

FIG. 12 illustrates an example of an image of a migration configuration window appearing after the destination storage apparatus Str\_X has been selected in the Select Destination Storage Apparatus window shown in FIG. 9;

FIG. 13 illustrates an example of a Create Destination Pool window;

FIG. 14 illustrates a configuration result after three pools have been created as destination pools;

FIG. 15 illustrates an example of a Select Logical Volume to Allocate window to be displayed in response to drop of an icon;

FIG. 16 is a flowchart illustrating an example of a method for a GUI display control program to create a logical volume list in the Select Logical Volume to Allocate window;

FIG. 17 illustrates an example of a destination pool configuration temporary information table;

FIG. 18 is a flowchart of the processing performed by the GUI display control program in response to press of a Confirm button 512;

FIG. 19 illustrates details of Step S124 in the flowchart of FIG. 18;

FIG. 20 illustrates an example of a source volume performance class table;

FIG. 21 illustrates an example of a performance increase/decrease indication boundary value table;

FIG. 22 illustrates an example of a Change Increase/Decrease Indication window created and displayed by the GUI display control program in response to press of a Change Increase/Decrease Indication button in the migration configuration window;

FIG. 23 illustrates an example of the migration configuration window updated by the GUI display control program after allocation of logical volumes to the pools in the destination storage apparatus;

FIG. 24 illustrates an example of an Add Source Volume window created and displayed by the GUI display control program in response to press of an Add Source Volume button in the migration configuration window;

FIG. 25 is a flowchart of processing of the GUI display control program to create a list of volumes to be displayed in the Add Source Volume window;

FIG. 26 is a flowchart of processing of the GUI display control program performed in response to press of a Confirm button in the Add Source Volume window;

FIG. 27 illustrates a configuration example of a volume migration configuration temporary information table;

FIG. 28 illustrates the migration configuration window after addition of source volumes through the processing with the Add Source Volume window;

FIG. 29 illustrates an example of a Select Source Volume window displayed in response to drop of an icon;

FIG. 30 is a flowchart illustrating an example of processing to create a source volume list in the Select Source Volume window;

FIG. 31 is a flowchart illustrating an example of processing of the GUI display control program in response to press of a Confirm button in the Select Source Volume window;

FIG. 32 illustrates the volume migration configuration temporary information table after destination pools have been specified for source volumes;

FIG. 33 illustrates the migration configuration window after destination pools have been specified;

FIG. 34 illustrates an example of the migration configuration window allowing a choice between storage apparatuses and hosts as a basis to form source volume groups; and

FIG. 35 illustrates an example of receiving selection of a source volume group to be indicated in the migration configuration window.

#### DETAILED DESCRIPTION OF THE EMBODIMENTS

Hereinafter, an embodiment of this invention is described with reference to the accompanying drawings. It should be noted that the embodiment is merely an example to realize this invention and is not to limit the technical scope of this invention. Throughout the drawings, elements common to some drawings are denoted by the same reference signs unless particularly mentioned.

This embodiment discloses a system and a method for supporting planning of volume migration between storage systems. This system indicates the sizes of volumes allocated from each storage device group to destination pools and the sizes of volumes to be migrated from each storage device group to destination pools in the same window. As a result, the storage administrator can grasp the pool configuration in a destination storage apparatus and the relationship between volumes and destination pools through the image on the display, achieving effective planning in view of volume performance before and after the migration.

The system of this embodiment categorizes source volumes into groups and indicates the sizes of volumes to be migrated from the source volume groups to destination pools. Further, it categorizes the storage devices in the destination storage apparatus into groups and indicates the sizes of volumes allocated from the storage device groups to the destination pools. As a result, the storage administrator can easily

grasp the overall storage system even if a large number of source volumes and destination storage devices exist.

The system of this embodiment further accepts instructions specifying the sizes of volumes to be allocated to the destination pools and the sizes of volumes to be migrated to the destination pools with the image on the display. As a result, the storage administrator can determine the configuration of destination pools and the destinations of volumes to be migrated while overlooking both of the source storage apparatuses and the destination storage apparatus.

FIG. 1 is a block diagram schematically illustrating a general configuration of a computer system in this embodiment. The computer system includes a host apparatus (hereinafter, occasionally referred to as host), a management computer 102, a plurality of source storage apparatuses 105, and a plurality of destination storage apparatuses 106. The numbers of host apparatuses, management computers, and storage apparatuses each depend on the design.

The host apparatus 101, the management computer 102, and the storage apparatuses 105 and 106 are connected to be able to communicate with one another via a management network 103. In an example, the management network 103 is an IP network. The management network 103 may also be a network other than the IP network as far as it is a network for data communication.

The host apparatus 101 and the storage apparatuses 105 and 106 are connected via a data network 104. The host apparatus 101 is an apparatus that accesses the resources of the storage apparatuses 105 and 106 to provide services. The data network 104 is a network for data communication; in an example, it may be a SAN (Storage Area Network). The data network 104 may be a network other than the SAN as far as it is a network for data communication. The data network 104 and the management network 103 may be the same network.

The storage apparatuses 105 and 106 have different specifications but can have the same basic configuration. Accordingly, a configuration example of the storage apparatus 106 is specifically described hereinafter. FIG. 2 illustrates an example of the hardware configuration of the storage apparatus 106.

The storage apparatus 106 includes a first storage device group 207, a second storage device group 208, a third storage device group 209, and a controller 210. For example, the first storage device group 207, the second storage device group 208, and the third storage device group 209 are an SLC SSD (Single Level Cell Solid State Drive) group, an MLC SSD (Multi Level Cell Solid State Drive) group, and a SAS HDD (Serial Attached SCSI Hard Disk Drive) group, respectively. The source storage apparatus 105 may have only a single type of storage devices.

The controller 210 includes a processor 203, a program memory 206, a cache memory 204, a disk controller 205, a data interface 201, and a management interface 202. These are connected to be able to communicate with one another via an internal bus 215.

The processor 203 (controller 210) executes a storage control program and other necessary programs to implement predetermined functions including control of I/Os from the host apparatus 101 and management and control of pools and volumes in the storage apparatus 106. The program memory 206 stores programs executed by the processor 203 and data therefore.

The cache memory 204 temporarily stores user data of the host apparatus 101. Specifically, it temporarily stores write data from the host apparatus 101 and then transfers it to one of the storage device groups 207 to 209. It also temporarily

5

stores read data to be transferred from one of the storage device groups 207 to 209 to the host apparatus 101.

The disk controller 205 has a function to convert a protocol used for communication between the storage device groups 207 to 209 and the controller 210 into a protocol used inside the storage controller 210. The data interface 201 and the management interface 202 are connected to the data network 104 and the management network 103, respectively, and have functions to convert the respective protocols used for communication in the networks to a protocol used inside the controller 201.

FIG. 3 schematically illustrates an example of logical configuration of volumes the destination storage apparatus 106 provides to the host apparatus 101 and an example of relationship among the volumes and the storage device groups 207 to 209. The source storage apparatus 105 may provide pools and virtual volumes or alternatively, may provide only normal logical volumes.

The controller 210 configures a pool 320 that consists of a plurality of unit storage areas (pages). In the example of FIG. 3, the pool 320 consists of a plurality of logical volumes (real volumes) and each logical volume consists of a plurality of pages. The controller 210 can create a plurality of pools. The controller 210 creates a virtual volume 301 that is allocated storage areas (pages) in the pool 320. The virtual volume 301 is provided to the host apparatus 101.

The pool is hierarchically tiered into a plurality of storage tiers, which may be different in access performance capability. In this example, the pool 320 consists of three storage tiers 321 to 323. The storage tier 1 (321) has the highest access performance capability and the storage tier 3 (323) has the lowest. In this example, the storage tiers 321 to 323 include logical volumes 303 to 305, respectively, by way of example. The storage tiers 321 to 323 each include one or more logical volumes.

The storage device groups 207 to 209 provide storage areas for the storage tiers 321 to 323, respectively. The first storage device group 207 is composed of a first type of storage devices; FIG. 3 shows two first-type storage devices 309a and 309b, by way of example. The second storage device group 208 is composed of second type of storage devices; FIG. 3 shows two second-type storage devices 310a and 310b, by way of example. The third storage device group 209 is composed of third type of storage devices; FIG. 3 shows two third-type storage devices 311a and 311b, by way of example.

The three types of storage devices in the storage device groups 207 to 209 are different in access performance capability. In this example, the first type of storage devices has the highest performance capability and the third type of storage devices have the lowest performance capability. The access performance is expressed in indices such as response time and throughput. Typically, redundant arrays of inexpensive disks (RAID) composed of a plurality of storage devices provide a plurality of logical volumes.

The controller 210 configures logical volumes different in access performance capability from storage areas provided by the storage device groups 207 to 209. As mentioned above, the logical volume 303 composed of storage areas of the storage device group 207 has the highest access performance capability and the logical volume 305 composed of storage areas of the storage device group 209 has the lowest access performance capability.

In the pool 320, each volume is composed of a plurality of pages. Pages are unit storage areas to manage virtual volumes and pools. In the example of FIG. 3, the logical volume 303 includes pages 315a and 315b. The logical volume 304

6

includes pages 316a and 316b. The logical volume 305 includes pages 317a and 317b.

A volume provided to the host apparatus 101 is a virtual volume and its capacity is virtualized. Every time the virtual volume 301 is written by the host apparatus 101 to become in need of a data storage area, the controller 210 allocates a page to the virtual volume 301. In the example of FIG. 3, the virtual volume 301 includes virtual pages 302a to 302d.

The virtual pages 302a to 302d have been allocated logical pages (real pages): the virtual page 302a has been allocated the logical pages 315a in the logical volume 303 of the storage tier 1 (321); the virtual page 302b has been allocated the logical page 315b in the logical volume 303 of the storage tier 1 (321); the virtual page 302c has been allocated the logical page 317b in the logical volume 305 of the storage tier 3 (323); and the virtual page 302d has been allocated the logical page 316a in the logical volume 304 of the storage tier 2 (322).

The storage apparatus 106 can configure the capacity of the virtual volume 301 recognized by the host apparatus 101 larger than the real size (total size of all logical pages) allocated to the virtual volume 301.

In response to a write from the host apparatus 101 to an area in the virtual volume 301 which has not been allocated a page, the controller 210 newly allocates a logical page to the virtual volume 301. The controller 210 releases a logical page that has been allocated to the virtual volume 301 but does not hold user data.

In an example, in response to a write from the host apparatus 101 to the virtual volume 301, the controller 210 newly allocates a required size of page from the highest-class storage tier 1 (301) of the pool 320 to the virtual volume 301. The controller may determine the storage tier for the page to be written by a different method.

FIG. 4 illustrates an example of hardware configuration of the management computer 102 and an example of software configuration of the computer system. The management computer 102 includes a management interface 254, a processor 251, a memory 255 of a primary storage device, a secondary storage device 252, an input device 253, and a display device 256. The management computer 102 executes management software to work in accordance with it. The devices in the management computer 102 are connected via a bus to be able to communicate with one another.

The input device 253 includes one or more devices such as a pointer, a keyboard, and others. The administrator can operate the management computer 102 with these input devices 253 and the display device 256; alternatively, the administrator may access the management computer 102 from a client computer connected via a network 103. The client computer is included in the management system together with the management computer 102.

The administrator inputs necessary information with an input device 253 and checks the necessary information by sight with a display device 256. The management system may be configured with one or more computers; it may include a plurality of servers each having a part or all of the functions of the management computer 102.

The processor 251 executes programs held in the memory 255 to implement predetermined functions of the management computer 102. The memory 255 stores programs to be executed by the processor 251 and information required to execute the programs. The programs include not shown OS and other programs in addition to the management programs.

The management software includes a plurality of programs (modules) and information used by the programs. In this example, the management software includes a GUI display

control program 231, a storage information collection program 232, and a migration control program 233. Furthermore, the management software includes GUI temporary information tables 241, a virtual volume management table 242, a logical volume management table 243, a pool management table 244, and a RAID group management table 245.

In typical, the management software is loaded from the secondary storage device 252 to the memory 255. The secondary storage device 252 is a storage device including a non-volatile non-transitory storage medium for storing information (including programs and data) required to implement predetermined functions of the management computer 102. The secondary storage device 252 may be an external storage device connected via a network.

The source storage apparatus 105 includes a control program 151, a virtual volume management table 152, a logical volume management table 153, a pool management table 154, and a RAID group management table 155. The destination storage apparatus 106 includes a control program 161, a virtual volume management table 162, a logical volume management table 163, a pool management table 164, and a RAID group management table 165.

The control programs 151 and 161 control the storage apparatuses 105 and 106, respectively, so that they perform necessary processing. In this embodiment, the control programs 151 and 161 send and receive necessary information to and from the management computer 102 and further, update management information and perform volume migration in accordance with instructions from the management computer 102.

The management computer 102 acquires necessary information from the storage administrator and the storage apparatuses 105 and 106 to create and update tables. The storage information collection program 232 collects necessary information from the source storage apparatus 105 and the destination storage apparatus 106 and updates tables. The GUI display control program 231 updates tables in accordance with information acquired from the storage administrator through the input device 253.

The tables 242 to 245 in the management computer 102 each have united information of the information in the tables having the identical names in the storage apparatuses 105 and 106. As will be described later, the tables 242 to 245 in the management computer 102 include the IDs of the storage apparatuses in addition to the information of the tables having the identical names in the storage apparatuses 105 and 106.

The programs are executed by a processor to perform predetermined processing. Accordingly, a description having a subject of program in this embodiment may be replaced by a description having a subject of processor. Alternatively, processing performed by a program is processing performed by the apparatus (such as the storage apparatus 105 or 106, the management computer 102, or the host apparatus 101) and the system which run the program.

The processor operates in accordance with a program to work as a functional part (means) to implement a predetermined function. Moreover, the processor also works as functional parts to implement different processing executed by each program. The apparatus and the system including the processor are an apparatus and a system including these functional parts (means).

In this embodiment, the information used by the system does not depend on the data structure and may be expressed in any data structure. For example, a data structure appropriately selected from table, list, database, and queue can store the information. In describing the information, terms such as

identification information, identifier, name, ID, and number are used; these are replaceable with one another.

FIG. 5 is a configuration example of the RAID group management table 245 in the management computer 102. The RAID group management table 245 manages association relations between storage devices in the storage apparatuses 105 and 106 and RAID groups and characteristics of the RAID groups. The term "characteristics of a RAID group" inclusively represents the capacity and the I/O performance capability of the RAID group. In this embodiment, the I/O performance is expressed in [IOPS/GB], but the unit of measurement of performance is not limited to this.

The storage information collection program 232 collects information from the RAID group management tables 155 and 165 in the storage apparatuses 105 and 106 and stores it in the RAID group management table 245. The RAID group management tables 155 and 165 each manage only the local RAID groups of an apparatus. However, the RAID group management table 245 has a column for storing the IDs of storage apparatuses so as to manage information of a plurality of storage apparatuses.

The "RAID group performance" indicates an estimated I/O performance value of a logical volume cut out from a RAID group. In the example of FIG. 5, the RAID group performance is equal to the storage device performance of the storage devices constituting the RAID group. Unlike this, the RAID group performance value may be calculated by a function of a variable of the storage device performance. The control program 151 or 161 in the storage apparatus or the storage information collection program 232 calculates the RAID group performance with a formula equipped therewith beforehand.

In this example, the RAID group IDs are identifiers unique to a storage apparatus. A RAID group consists of a plurality of storage devices and the number of storage devices constituting a RAID group depends on the design. The "storage media type" of a RAID group is the same as the type of the storage devices constituting the RAID group. In this embodiment, a RAID group consists of the same storage media type of storage devices.

FIG. 6 illustrates a configuration example of the logical volume management table 243 in the management computer 102. The logical volume management table 243 manages association relations between logical volumes and their owner apparatuses and characteristics of the logical volumes.

The storage information collection program 232 collects information from the logical volume management tables 153 and 163 in the storage apparatuses 105 and 106 and stores it in the logical volume management table 243. The logical volume management tables 153 and 163 each manage only the local logical volumes of an apparatus. However, the logical volume management table 243 manages information of a plurality of storage apparatuses; accordingly, it includes a column for storing the IDs of the storage apparatuses.

The term of owner apparatus of a logical volume inclusively represents the storage apparatus providing the logical volume, the host apparatus that accesses the logical volume, and the RAID group from which the logical volume is cut out. The logical volume management table 243 further includes the pool to which the logical volume is allocated. If any value is contained in the column of "assigned host" or "assigned pool", the logical volume is in use.

The term of characteristics of a logical volume inclusively represents the capacity and the I/O performance capability ("logical volume performance") of the logical volume. The "logical volume performance" indicates the estimated I/O performance value of the logical volume. In the example of

FIG. 6, the logical volume performance is equal to the RAID group performance of the RAID group from which the logical volume is cut out. Unlike this, the logical volume performance may be calculated by a function of a variable of the storage device performance. The control program 151 or 161 in the storage apparatus or the storage information collection program 232 calculates the logical volume performance with a formula equipped therewith beforehand.

FIG. 7 illustrates a configuration example of the pool management table 244 in the management computer 102. The pool management table 244 manages characteristics of pools and association relations between pools and logical volumes allocated to the pools.

The storage information collection program 232 collects information from the pool management tables 154 and 164 in the storage apparatuses 105 and 106 and stores it in the pool management table 244. The pool management tables 154 and 164 each manage only the local pools of an apparatus. However, the pool management table 243 manages information of a plurality of storage apparatuses; accordingly, it includes a column for storing the IDs of the storage apparatuses.

The term of characteristics of a pool inclusively represents the capacity and the I/O performance capability ("pool performance") of the pool. The "pool performance" indicates an estimated I/O performance value of a virtual volume cut out from the pool. The control program 151 or 161 in the storage apparatus or the storage information collection program 232 calculates the value with a formula equipped therewith beforehand and stores the calculated value in the column of the "pool performance".

Various formulae can be considered to calculate the pool performance. For example, the following formula may be used:  $\text{Pool performance} = \Sigma(\text{Performance of a logical volume of the pool} \times \text{Capacity of the same logical volume} \pm \text{Capacity of the pool})$ . In this formula,  $\Sigma$  represents the sum for all the logical volumes constituting the pool.

FIG. 8 illustrates a configuration example of the virtual volume management table 242 in the management computer 102. The virtual volume management table 242 manages association relations between virtual volumes and owner apparatuses, association relations between virtual volumes and pools the virtual volumes belong to, and characteristics of the virtual volumes. In this example, a source volume in migration is a virtual volume; however, the source volume may be a logical volume.

The storage information collection program 232 collects information from the virtual volume management tables 152 and 162 in the storage apparatuses 105 and 106 and stores it in the virtual volume management table 242. The virtual volume management tables 152 and 162 each manage only the local virtual volumes of an apparatus. However, the virtual volume management table 242 manages information of a plurality of storage apparatuses; accordingly, it includes a column for storing the IDs of the storage apparatuses.

The term of owner apparatus of a virtual volume inclusively represents the storage apparatus providing the virtual volume and the host apparatus that accesses the virtual volume. The term of characteristics of a virtual volume inclusively represents the maximum size, the actual size in use, and the performance capability ("virtual volume performance") of the virtual volume.

The "virtual volume performance" indicates an estimated performance value of a virtual volume. In the example of FIG. 8, the virtual volume performance is equal to the pool performance of the pool from which the virtual volume is cut out. Unlike this, it may be calculated with a formula held by the control program 151 or 161 in the storage apparatus or the

storage information collection program 232 beforehand or alternatively, an actual measured value may be stored.

Hereinafter, configuring volume migration with the management computer 102 is described. The storage administrator can select a destination storage apparatus 106 and specify a pool configuration in the destination storage apparatus 106 with the management computer 102. Further, the storage administrator can specify source volumes and destination pools of the source volumes with the management computer 102.

First, an example of a configuration result is described. FIG. 33 illustrates an example of an image indicating a result of configuration of volume migration in this embodiment. The GUI display control program 231 creates image data of this image. This example is to migrate volumes from three source storage apparatuses Str\_A, Str\_B, and Str\_C to one destination storage apparatus Str\_X.

The source volumes are logical volumes or virtual volumes. The storage administrator configures migration of all or a part of the volumes in the three source storage apparatuses Str\_A, Str\_B, and Str\_C. Migration of all volumes in one storage apparatus is also called storage apparatus migration.

In this example, the management computer 102 uses the same GUI image to receive inputs of configuration data as well as to display a configuration result. The management computer 102 may display an image showing a configuration result different from an image for receiving configuration data. A migration configuration window 35 includes a Create Destination Pool button 371, an Add Source Volume button 372, a Change Increase/Decrease Indication button 373, and an Execute Migration button 374; details of these buttons will be described later.

The migration configuration window 35 includes a volume destination configuration section 351 and a storage device allocation section 354. The volume destination configuration section 351 includes a source volume section 352 and a destination pool section 353. The storage device allocation section 354 includes a destination storage device section 355 and destination pool section 356.

The migration configuration window 35 includes a section 357. The section 357 includes destination pool sections 353 and 356, and a pool characteristics section 380. In this embodiment, a section included in a section is also called a subsection.

The volume destination configuration section 351 indicates relations between source volume groups (source volumes) and destination pools. Each row indicates information on one source volume group. A source volume group consists of one or more source volumes. Indicating information on each source volume group instead of each source volume allows the storage administrator to easily grasp the entirety of the destination pools and the source volumes.

The source volume section 352 indicates the source storage apparatus to which the source volume group belongs, I/O performance capability of the source volume group, and the volume size for which destination pools have not been determined (the size of destination undetermined volumes) for each source volume group. The I/O performance capability will be described later. The volume size represents a total size of source volumes.

In this example, the source volume groups are formed depending on the storage apparatus including the source volume and the I/O performance. That is to say, source volumes belonging to the same storage apparatus and the same I/O performance class belong to the same source volume group. Categorizing the source volumes into groups depending on

## 11

the I/O performance enables clear indication of changes in I/O performance between before and after volume migration. The performance class of source volumes will be described later.

The size of destination undetermined volumes is indicated, in each cell, with a numerical value and a horizontal bar having a length corresponding to the numerical value. The broken line indicates the total volume size of the source volume group. For example, as to the source volume group having an I/O performance capability of "15K-17K" in the storage apparatus Str\_A, the size of destination undetermined volumes is 100 GB.

The destination pool section **353** indicates the sizes of volumes to be migrated from each source volume group to individual pools. In this example, three pools Pool\_1, Pool\_2, and Pool\_3 are prepared and each column indicates information on a pool.

A cell for a source volume group in a column of a pool indicates the size of volumes to be migrated from the source volume group to this pool. The cell indicates the size of volumes to be migrated with a numerical value and a horizontal bar having a length corresponding to the numerical value. For example, the sizes of volumes to be migrated from the source volume group having an I/O performance capability of 15K-17K in the storage apparatus Str\_A to the pools Pool\_1, Pool\_2, and Pool\_3 are 100 GB, 200 GB, and 0 GB, respectively.

A pool column has a width corresponding to the capacity of the pool. The relationship between the capacity of the pool and the width of the pool column applies to the relationship between the size of volumes to be migrated to the pool and the length of the horizontal bar. In each pool column, the horizontal bars representing the sizes of volumes to be migrated are disposed so as not to overlap in the row direction and correspond to a single bar in a stacked bar graph. Indicating the pool capacity of a pool and the sizes of volumes to be migrated to the pool in such a stacked bar graph enables the storage administrator to easily understand their relations.

The destination pool section **353** indicates the size of used space of each pool in the bottom row. The size of the used space is equal to the total size of volumes to be migrated. The used space of each pool may be indicated with a horizontal bar like the size of volumes to be migrated.

In the destination pool section **353**, the horizontal bars representing the volumes to be migrated have graphic patterns corresponding to the rates of increase or decrease in volume performance. The storage administrator can easily note the changes in performance between before and after volume migration to determine the destinations in accordance with the changes.

In this example, the increase/decrease rate in volume performance is classified into four ranges: increase by 50% or more, increase by 20% or more and less than 50%, increase/decrease by less than 20%, and decrease by 20% or more. The performance increase/decrease indication ranges are defined beforehand or defined by inputs of the storage administrator. The increase or decrease in performance between before and after migration can be calculated from the I/O performance of the source volume group and the I/O performance of the destination pool. The performance classes for source volume groups are determined depending on the performance increase/decrease indication ranges. These will be described later.

The storage device allocation section **354** indicates information on characteristics of each storage device group in the destination storage apparatus and the volume size allocated

## 12

from each storage device group to individual pools. A row indicates information on a storage device group.

In this example, the storage devices groups are formed based on the storage media type and the I/O performance. That is to say, storage devices of the same storage media type and having the same I/O performance capability belong to the same storage device group. In this example, each storage device group corresponds to each tier of the pools. Multiple storage device groups may provide their storage areas to a tier. For example, storage device groups of different storage media types and having the same I/O performance capability may provide their storage areas to a tier.

The destination storage device section **355** indicates characteristic information on each storage device group in the destination storage apparatus. Each row indicates information on a storage device group, in this example, information of the storage media type, the I/O performance capability, the total volume size, and the size of volumes unallocated to a pool with respect to the storage device group. The size of unallocated volumes is indicated with a numerical value and a horizontal bar, which has a length corresponding to the numerical value for the size of unallocated volumes.

The destination pool section **356** indicates the sizes of volumes allocated from each storage device group to individual pools. In this example, three pools, Pool\_1, Pool\_2, and Pool\_3 are prepared and each column indicates information on a pool.

A cell for a storage device group in a pool column indicates the size of volumes allocated from the storage device group to this pool. The cell indicates the size of allocated volumes with a numerical value and a horizontal bar having a length corresponding to the numerical value. For example, the sizes of volumes allocated from the second storage device group (SSD (MLC), 20K [IOPS/GB]) to the pools Pool\_1, Pool\_2, and Pool\_3 are 200 GB, 300 GB, and 0 GB, respectively.

A pool column has a width corresponding to the capacity of the pool. In this example, the widths of the pool columns in the destination pool section **356** are the same as the widths of the columns of the same pools in the destination pool section **353** and the columns of these sections are aligned in the row direction.

In each pool column, the horizontal bars representing the allocated volumes are disposed so as not to overlap in the row direction and correspond to a single bar in a stacked bar graph. Indicating the pool capacity of a pool and the sizes of volumes allocated to the pool in such a stacked bar graph enables the storage administrator to easily understand their relations.

The pool characteristics section **380** indicates characteristic information on each pool. In this example, the pool characteristics section **380** indicates the I/O performance capability, the capacity, and the size of unused space of each pool in numerical values. The pool columns for the pools Pool\_1, Pool\_2, and Pool\_3 are continued from the columns of the corresponding pools in the destination pool section **356**.

As described above, this example indicates the sizes of volumes allocated from each storage device group in the destination storage apparatus to the pools, the volume sizes of the source volume groups, and the sizes of volumes to be migrated from each source volume group to the pools. The storage administrator can pursue planning of volume migration between storage apparatuses considering performance of volumes before and after the migration even if the migration is for a large number of source volumes.

In the example of FIG. 33, the cells indicating both of a horizontal bar and a numerical value may indicate either one of them. The change in I/O performance capability between before and after the volume migration may be indicated by a

13

manner different from the graphic pattern of the horizontal bar or omitted from the indication. The horizontal bars in one column may be started from the same position in the row direction.

The management computer **102** can provide the same information in FIG. **33** with a different image configuration. For example, the relationship between rows and columns in the foregoing example may be opposite. The source volume groups may be defined on a basis different from the I/O performance capability, for example, the capacity.

Hereinafter, described is an example of a procedure using the volume migration GUI to obtain the example of the configuration result shown in FIG. **33**. FIG. **9** is an example of a Select Destination Storage Apparatus window **21** which appears first after start-up of the volume migration GUI. The GUI display control program **231** creates this image and outputs it to the display device **256**.

The display device **256** presents this image to the storage administrator. The storage administrator selects a destination storage apparatus **106** from a pull-down list in a section **211** in the Select Destination Storage Apparatus window **21**. Upon selection of a Confirm button **212**, the processing of a flowchart in FIG. **11** is started, which will be described later.

FIG. **10** illustrates a configuration example of an available storage device table **247** in the management computer **102**. The available storage device table **247** is included in the GUI temporary information tables **241** in the management computer **102**. The available storage device table **247** stores information on logical volumes that can be allocated to a pool in the selected destination storage apparatus **106**. This table **247** is created in accordance with the processing flow of FIG. **11** when the storage administrator presses the Confirm button **212** in the GUI image shown in FIG. **9** after selecting the destination storage apparatus **106**.

FIG. **11** is a flowchart of an example of processing to create or update the available storage device table **247**. The GUI display control program **231** operates in accordance with this flowchart. In response to selection of the Confirm button **212** with the input device **253**, the GUI display control program **231** selects unused logical volumes in the storage apparatus selected as the destination from the logical volume management table **243** (**S101**). The unused logical volumes are logical volumes for which neither an "Assigned Host" nor an "Assigned Pool" is specified in the logical volume management table **243**.

The GUI display control program **231** searches the RAID group management table **245** for the selected logical volumes using their respective RAID group IDs as keys to acquire the "Storage Media Type" of the logical volumes (**S102**). The GUI display control program **231** stores information of the IDs, the capacities, and the performance capabilities of the logical volumes acquired from the logical volume management table **243** and information of the storage media types acquired from the RAID group management table **245** to the available storage device table **247** (**S103**).

FIG. **12** illustrates an example of an image of the migration configuration window **35** which is presented after the destination storage apparatus Str\_X has been selected in the Select Destination Storage Apparatus window **21** in FIG. **9**. The destination storage device section **355** in the storage device allocation section **354** indicates information on the media types of the destination storage apparatus Str\_X. The source volumes and the pool configuration of the destination storage apparatus Str\_X have not been specified yet; the cells in the other sections are blank.

The GUI display control program **231** categorizes the storage devices available in the destination storage apparatus

14

Str\_X by storage media type and logical volume performance capability into groups with reference to the available storage device table **247**. In this example, three groups different in storage media type are created. Categorizing the available storage devices into groups allows the storage administrator to easily grasp the entirety even if the destination storage apparatus has a large number of logical volumes.

The GUI display control program **231** further calculates the total size of volumes of each storage device group. The GUI display control program **231** creates image data for the migration configuration window **35** including the information on the storage devices in the destination storage apparatus Str\_X obtained by the calculation and outputs it to the display device **256**.

The GUI display control program **231** receives designation of source volumes and destination pools through inputs to the volume destination configuration section **351**. Further, it receives instructions to create pools and specifications about which storage device group should allocate how much space to each pool.

When the storage administrator presses the Create Destination Pool button **371** in the migration configuration window **35** of FIG. **12** with the input device **253**, the GUI display control program **231** outputs image data for a Create Destination Pool window **41** shown in FIG. **13** to the display device **256**. The storage administrator enters a pool ID for the pool to be created in the field **411**.

Upon press of a Confirm button **412**, the GUI display control program **231** creates a column for the pool in the destination pool section **357** (subsections **353**, **356**, and **380**) in the migration configuration window **35**. The storage administrator may repeat pressing the Create Destination Pool button **371** to create a plurality of pools.

FIG. **14** shows a configuration result after creation of three pools Pool\_1, Pool\_2, and Pool\_3 as destination pools. Although the pools Pool\_1, Pool\_2, and Pool\_3 have been defined, the pools Pool\_1, Pool\_2, and Pool\_3 have not been allocated logical volumes (storage areas of storage devices) yet.

The GUI display control program **231** receives instructions for allocation of a logical volume (a storage area of a storage device) to a pool by drag and drop of an icon **361** (graphic component). This operation enables easy configuration on the same window. Each row in the destination storage device section **355** includes an icon **361**.

The storage administrator drags and drops the icon **361** from the destination storage device section **355** to a cell in the destination pool section **356**. Through this operation, some space can be allocated from the storage device group corresponding to the cell where the icon **361** is included to the pool corresponding to the cell where the icon is dropped. In the example of FIG. **14**, the GUI display control program **231** allocates some space from the storage device group of SSD (SLC) to the pool Pool\_2.

FIG. **15** illustrates an example of a Select Logical Volume to Allocate window **51** to be displayed in response to drop of the icon **361**. The GUI display control program **231** creates image data for the Select Logical Volume to Allocate window **51** and outputs it to the display device **256**.

The Select Logical Volume to Allocate window **51** indicates a list **511** of unused logical volumes in the selected storage device group. The logical volumes in the list **511** are candidate logical volumes to be allocated to the selected destination pool. In this example, the list **511** indicates characteristics of the logical volumes, which are the storage media type, the I/O performance capability, and the capacity.

15

FIG. 16 is a flowchart illustrating an example of the method for the GUI display control program 231 to create the list of logical volumes in the Select Logical Volume to Allocate window 51. The GUI display control program 231 selects the logical volumes in the selected storage device group from the available storage device table 247 (S111). As described above, storage device groups are identified by the storage media type and the logical volume performance capability.

The GUI display control program 231 excludes the logical volumes that have already been allocated to some destination pool from the logical volumes selected from the available storage device table 247.

Specifically, the GUI display control program 231 searches a destination pool configuration temporary information table 248. The destination pool configuration temporary information table 248 indicates logical volumes that have already been allocated to pools. Details of the destination pool configuration temporary information table 248 will be described later. If any logical volume is included in the destination pool configuration temporary information table 248, the GUI display control program 231 excludes the logical volume from the logical volumes to be indicated in the list 511 (S112).

FIG. 17 illustrates an example of the destination pool configuration temporary information table 248. The destination pool configuration temporary information table 248 is included in the GUI temporary information tables 241. The destination pool configuration temporary information table 248 holds configuration information for allocation of logical volumes (areas of storage devices) to pools specified in the migration configuration window 35.

The destination pool configuration temporary information table 248 indicates logical volumes allocated to each pool in the destination storage apparatus 106. In this example, the destination pool configuration temporary information table 248 includes characteristic information on logical volumes in addition to the elements in the pool management table 244.

In this example, the destination pool configuration temporary information table 248 indicates the capacity and the I/O performance capability of each pool. Furthermore, it indicates the capacity, the I/O performance capability, and the storage media type of each logical volume. The GUI display control program 231 acquires information on each logical volume from the available storage device table 247. The GUI display control program 231 calculates the I/O performance capability of each pool in accordance with a predetermined formula.

The characteristic information, namely, the capacity, the I/O performance capability, and the storage media type, on each logical volume may be omitted. The destination pool configuration temporary information table 248 including this information enables speedy update of the information indicated in the migration configuration window 35.

Returning to FIG. 15, the GUI display control program 231 receives selection of logical volumes by check in the corresponding check boxes. Upon press of the Confirm button 512, the GUI display control program 231 performs the processing in accordance with the flowchart of FIG. 18.

In the flowchart of FIG. 18, the GUI display control program 231 adds information on the logical volumes selected in the Select Logical Volume to Allocate window 51 to the destination pool configuration temporary information table 248 (S121). The GUI display control program 231 adds entries for the selected logical volumes to be the entries of the designated pool. The GUI display control program 231 acquires characteristic information on the logical volumes from the available storage device table 247.

16

The GUI display control program 231 recalculates the pool capacity and pool performance capability of each pool (S122). The pool capacity is a total size of all the logical volumes allocated to the pool and the pool performance capability is calculated from I/O performance capabilities of the allocated logical volumes in accordance with a predetermined formula.

If pool performance capability of any pool has changed (S123: YES), the GUI display control program 231 updates a source volume performance class table 246 and a volume migration configuration temporary information table 249 (S124).

FIG. 19 illustrates details of Step 124 in the flowchart of FIG. 18. Before describing the flowchart of FIG. 19, a source volume performance class table 246 and a performance increase/decrease indication boundary table 292 are described. FIG. 20 illustrates an example of the source volume performance class table 246 and FIG. 21 illustrates an example of the performance increase/decrease indication boundary table 292.

The source volume performance class table 246 is included in the GUI temporary information tables 241. The source volume performance class table 246 indicates classes of I/O performance capability to be the references to define source volume groups. The source volumes constituting a source volume group are included in the same performance class. The source volume performance class table 246 defines each performance class with the lowest performance and the highest performance.

The performance increase/decrease indication boundary table 292 is included in the GUI temporary information tables 241. The performance increase/decrease indication boundary table 292 holds boundary values in indication of increase/decrease in performance capability between before and after migration in the migration configuration window 35. The example of FIG. 21 defines four performance increase/decrease indication ranges: increase by 50% or more, increase by 20% or more and less than 50%, increase/decrease by less than 20%, and decrease by 20% or more.

The GUI display control program 231 calculates source volume performance classes from the boundary values in performance increase/decrease indication between before and after migration. As a result, the volumes migrated from the same source volume group to the same pool will be in the same performance increase/decrease indication range.

Returning to FIG. 19, the GUI display control program 231 acquires all pool performance values of the created pools from the destination pool configuration temporary information table 248 (S131). The GUI display control program 231 calculates products of the acquired pool performance values and each boundary value in the performance increase/decrease indication boundary table 292 (S132). The GUI display control program 231 sorts the obtained values in descending order and excludes duplicate values (S133).

The GUI display control program 231 stores the remaining values to the source volume performance class table 246 in descending order (S134). As a result, the performance classes of the source volumes are redefined in accordance with the change in pool performance. With the new performance classes, the volumes migrated from the same source volume group to the same pool are in the same performance increase/decrease indication range.

The GUI display control program 231 updates the performance classes of the source volumes in the volume migration configuration temporary information table 249 in accordance with the redefined performance classes (S135). As will be described later with reference to FIG. 27, the volume migra-



17

tion configuration temporary information table **249** manages relations between source volumes and destination pools specified in the migration configuration window **35** and has a column of performance classes of source volumes.

FIG. **22** illustrates an example of a Change Increase/Decrease Indication window **73**, which is created and displayed by the GUI display control program **231** in response to press of the Change Increase/Decrease Indication button **373** in the migration configuration window **35**. The GUI display control program **231** receives changes in boundary values in performance increase/decrease indication through the Change Increase/Decrease Indication window **73**.

When the Confirm button **731** is pressed after values are entered in the Change Increase/Decrease Indication window **73**, the GUI display control program **231** updates the performance increase/decrease indication boundary table **292** with the entered values. Upon update of the performance increase/decrease indication boundary table **292**, the GUI display control program **231** executes the processing according to the flowchart of FIG. **19**.

FIG. **23** illustrates an example of the migration configuration window **35** updated by the GUI display control program **231** after allocation of logical volumes to the pools Pool\_1, Pool\_2, and Pool\_3 in the destination storage apparatus.

The destination pool section **356** indicates the sizes of logical volumes allocated to each pool on a storage device group basis. One cell represents a total size of logical volumes allocated from one storage device group to one pool.

In the destination pool section **356**, each column indicates information on the sizes of volumes allocated to a pool; from the top to the bottom, the sizes of volumes allocated from storage device groups are provided in descending order of performance capability. In each pool column, horizontal bars are disposed so as not to overlap in the row direction. In this way, each pool column indicates the sizes of volumes allocated from storage device groups in the form of a stacked bar graph.

The GUI display control program **231** determines the lengths of the horizontal bars and the widths of the pool columns in accordance with the sizes of the allocated volumes. For example, the GUI display control program **231** determines the lengths of the horizontal bars and the width of the pool column based on the products of a proportionality coefficient and the sizes of allocated volumes. In the destination pool sections **356** and **353**, the widths of the columns of the same pool are the same.

The GUI display control program **231** calculates values of the pool performance, the pool capacity, and the unused pool space to be indicated in the pool characteristics section **380** for each pool from the size of volumes allocated to each pool. The pool performance is calculated from the performance capabilities and the sizes of allocated volumes of the storage device groups with a predetermined formula. The pool capacity and the unused pool space are both the total size of volumes allocated to the pool.

In the destination storage device section **355**, the size of unallocated volumes in each storage device group decreases in accordance with the size of volumes allocated to the pools. The GUI display control program **231** subtracts the size of allocated volumes from the total size of volumes in each storage device group to obtain the size of unallocated volumes and determines the length of the horizontal bar in accordance with the value. For example, it employs the same method of calculating the lengths of horizontal bars in the destination pool section **356**.

FIG. **24** illustrates an example of an Add Source Volume window **72** created and displayed by the GUI display control

18

program **231** in response to press of an Add Source Volume button **372** in the migration configuration window **35**. The GUI display control program **231** receives selection of source volumes through the Add Source Volume window **72**.

The storage administrator designates a source storage apparatus in the Add Source Volume window **72** and further designates source volumes among the volumes in the source storage apparatus. Press of a Confirm button **721** fixes the inputs.

FIG. **25** is a flowchart of the processing of the GUI display control program **231** to create a list of volumes to be displayed in the Add Source Volume window **72**. The GUI display control program **231** acquires a list of virtual volumes from the virtual volume management table **242** (S141). The list includes information to be indicated in the Add Source Volume window **72**; in this example, information on the owner storage apparatus and the characteristics of each virtual volume is included.

The GUI display control program **231** excludes virtual volumes included in the volume migration configuration temporary information table **249** from the foregoing virtual volume list (S142). As will be described later, the volume migration configuration temporary information **249** manages source volumes that have already been selected. Accordingly, created is a list of unselected volumes.

Upon press of the Confirm button **721** in the Add Source Volume window **72** in FIG. **24**, the GUI display control program **231** executes the processing illustrated in the flowchart in FIG. **26**. The GUI display control program **231** stores the information on the selected virtual volumes in the volume migration configuration temporary information table **249**. The GUI display control program **231** identifies the performance classes to which the virtual volumes belong and stores the IDs of the identified performance classes in the volume migration configuration temporary information table **249**.

FIG. **27** illustrates a configuration example of the volume migration configuration temporary information table **249**. The volume migration configuration temporary information table **249** is included in the GUI temporary information tables **241**. The volume migration configuration temporary information table **249** holds information on the source volumes and their respective destination pools selected with the GUI in this embodiment.

FIG. **27** shows the volume migration configuration temporary information table **249** after source volumes have been added through the processing with the Add Source Volume window **72**. In FIG. **27**, the volume migration configuration temporary information table **249** holds information on the source volumes but does not hold information on the destination pools since the destination pools have not been specified yet, and holds only information on the destination storage apparatus Str\_X for the information on the destination.

The volume migration configuration temporary information table **249** stores information on the owner apparatuses and the characteristics of the source volumes. For the information on the owner apparatuses in this example, the owner storage apparatus and the assigned host are held. For the characteristic information, the maximum size, the actual size in use, the volume performance, and the performance class are held. The volume migration configuration temporary information table **249** further holds information on the storage apparatus and the pool performance of the destination pool, and information on the performance increase/decrease between before and after volume migration.

The information on the maximum size, the actual size in use, the volume performance, and the assigned host of the virtual volume may be omitted since other tables hold the

same information. The volume migration configuration temporary information table **249** holding these items enables speedy update (creation) of the migration configuration window **35**.

The GUI display control program **231** updates the migration configuration window **35** with the information on the source volumes in the volume migration configuration temporary information table **249**. FIG. **28** shows the migration configuration window **35** after source volumes have been added through the processing with the Add Source Volume window **72**.

The GUI display control program **231** updates the information indicated in the source volume section **352** in response to the addition of source volumes. The GUI display control program **231** updates the source volume section **352** in response to every press of the Confirm button **721** in the Add Source Volume window **72**.

The GUI display control program **231** categorizes the source volumes into groups depending on the performance class to which the source volume belongs. The GUI display control program **231** gathers the source volumes in the same storage apparatus and belonging to the same performance class into a source volume group. The GUI display control program **231** calculates the capacity of each source volume group by summing the capacities of the source volumes in the source volume group.

The GUI display control program **231** creates and displays entries of the created source volume groups in the source volume section **352**. The GUI display control program **231** indicates the sizes of destination undetermined volumes in the source volume groups in numerals and graphs. Since no volumes are allocated to the pools, the size of each source volume group is equal to the size of the destination undetermined volumes.

The GUI display control program **231** receives designation of destination pools for source volumes (a source volume group) by drag and drop of an icon **362**. The operation of the icon **362** enables easy designation of a destination pool on the same window. Each row in the source volume section **352** includes an icon **362**.

The storage administrator drags and drops the icon **362** from the source volume section **352** to a cell in the destination pool section **353**. Through this operation, the volumes can be migrated from the source volume group of the cell including the icon **362** to the pool corresponding to the cell where the icon **362** is dropped.

In the example of FIG. **28**, volume migration is specified from the source volume group having a performance capability of 15K-17K in the storage apparatus Str\_B to the pool Pool\_2. The GUI display control program **231** may calculate and display the increase/decrease in performance in the destination pool before the drop.

FIG. **29** illustrates an example of a Select Source Volume window **61** to be displayed in response to drop of the icon **362**. The GUI display control program **231** creates image data for the Select Source Volume window **61** and outputs it to the display device **256**. This window offers easy configuration on the same window to the storage administrator.

The Select Source Volume window **61** indicates volumes in the source volume group designated in the migration configuration window **35**. The GUI display control program **231** receives selection of volumes to be migrated to the pool from the storage administrator. Upon press of the Confirm button **611**, the selection is fixed.

FIG. **30** illustrates a flowchart of an example of processing to create a source volume list in the Select Source Volume window **61**. The GUI display control program **231** selects the

virtual volumes of the source volume group designated in the migration configuration window **35** from the volume migration configuration temporary information table **249** (S161). The GUI display control program **231** selects the virtual volumes having the source storage apparatus ID and the performance class ID of the designated source volume group.

The GUI display control program **231** excludes the virtual volumes to which destination pool IDs have been assigned in the volume migration configuration temporary information table **249** from the virtual volumes selected at Step S161 (S162). The remaining virtual volumes are indicated in the Select Source Volume window **61**; they are selectable virtual volumes.

FIG. **31** illustrates a flowchart of an example of processing performed by the GUI display control program **231** in response to press of the Confirm button **611** in the Select Source Volume window **61**.

The GUI display control program **231** stores, in the volume migration configuration temporary information table **249**, information on the destination pool in the entries of the virtual volumes selected in the Select Source Volume window **61** (S171). The storage apparatus ID and the pool ID are values designated in the migration configuration window **35** and the value of the pool performance is acquired from the destination pool configuration temporary information table **248**.

The GUI display control program **231** calculates estimated performance increase/decrease from the performance capability of the volume and the performance capability of the destination pool for each source virtual volume and stores the result in each entry of the volume migration configuration temporary information table **249**. The GUI display control program **231** calculates the estimated performance increase/decrease based on the performance capability either before the migration or after the migration. To indicate the estimated performance increase/decrease before drop of the icon **362**, the GUI display control program **231** calculates and displays the estimated performance increase/decrease on the memory **255** without storing the pool information in the volume migration configuration temporary information table **249**.

FIG. **32** illustrates a volume migration configuration temporary information table **249** after destination pools have been specified for the source volumes. Each column of the destination pool holds information on the destination pool.

FIG. **33** illustrates the migration configuration window **35** after destination pools have been specified. The information appearing in the migration configuration window **35** in FIG. **33** has already been described. The GUI display control program **231** updates the migration configuration window **35** in response to every press of the Confirm button **611** in the Select Source Volume window **61**. The GUI display control program **231** updates the information in the volume destination configuration section **351** and the pool characteristics section **380**.

The GUI display control program **231** accepts a change in specification of the size of volumes allocated to a pool after fixing the destinations for a part or all of the source volumes through the migration configuration window **35**. The GUI display control program **231** updates the information in each section in the migration configuration window **35** in accordance with the change in pool configuration. Hence, the storage administrator can always grasp how the volume performance increases or decreases in the destination with change in configuration of destination pools.

When the pool configuration is changed, the GUI display control program **231** performs processing in accordance with the flowcharts of FIGS. **18** and **19**. Furthermore, the GUI display control program **231** updates the volume migration

21

configuration temporary information table **249**. The GUI display control program **231** updates the image of the volume destination configuration section **351** in accordance with the information in the updated volume migration configuration temporary information table **249**.

The redefined performance classes require update of the performance class IDs of the source volumes in the volume migration configuration temporary information table **249**. In the volume destination configuration section **351**, accordingly, the number of entries for source volume groups, the highest and lowest values of performance classes, the sizes of destination undetermined volumes, the sizes of volumes to be migrated to destination pools, the performance increase/decrease indication, and the like are updated.

Upon press of the Execute Migration button **374** in the migration configuration window **35**, the GUI display control program **231** sends the migration control program **233** an instruction to perform volume migration together with the configuration information.

In the foregoing example, each source volume group is composed of the volumes of the same source storage apparatus. Each source volume group can be composed of the volumes assigned to the same host. In an example, the GUI display control program **231** forms source volume groups on the basis of the storage apparatuses or hosts in accordance with designation by the storage administrator. In this way, source volume groups can be formed as desired by the user. The GUI display control program **231** can acquire information on the assigned hosts for the source volumes from the virtual volume management table **242**.

FIG. **34** illustrates an example of the migration configuration window **35** that allows choice between storage apparatuses and hosts as the basis to form source volume groups. The storage administrator chooses either storage apparatuses or hosts from a pull-down menu **363**. The GUI display control program **231** forms source volume groups in accordance with the chosen basis. That is to say, in the case of hosts, the GUI display control program **231** forms source volume groups with source volumes assigned to the same host and in the same performance class.

For example in the flowchart of FIG. **30**, the GUI display control program **231** selects virtual volumes in the designated source volume group from the volume migration configuration temporary information table **249**. At this step, the GUI display control program **231** selects virtual volumes of the entries including the assigned host and the performance class ID for the designated source volume group.

FIG. **35** illustrates an example of receiving selection of a source volume group to be indicated in the migration configuration window **35**. Upon selection of the "Filter" link, the GUI display control program **231** displays a filter section **364**. In the filter section **364**, the GUI display control program **231** accepts designation of an assigned host for the source volume groups to be indicated in the migration configuration window **35**.

The GUI display control program **231** unifies all the source volumes of the undesignated assigned hosts into one source volume group and displays this source volume group as one entry. As to the designated host, the GUI display control program **231** forms source volume groups as described above.

In the case where many hosts are assigned to the source volumes, this operation compresses the indication space to provide discriminable information in the migration configuration window **35**. Although FIG. **35** illustrates an example of filtering the hosts, the same filtering can apply to the storage

22

apparatuses. The GUI display control program **231** does not need to have the filtering function to form source volume groups.

This invention is not limited to the above-described embodiment but includes various modifications. The foregoing embodiment has been described in details for better understanding of this invention and is not limited to the one including all the configurations described above. A part of the configuration of one example may be replaced with that of another example; the configuration of one example may be incorporated to the configuration of another example. A part of the configuration of each example may be added, deleted, or replaced by that of a different configuration.

The above-described configurations, functions, and processing units, for all or a part of them, may be implemented by hardware: for example, by designing an integrated circuit. The above-described configurations and functions may be implemented by software, which means that a processor interprets and executes programs for implementing the functions. The information of programs, tables, and files to implement the functions may be stored in a storage device such as a memory, a hard disk drive, or an SSD (Solid State Drive), or a storage medium such as an IC card, or an SD card.

What is claimed is:

1. A storage management system for managing source storage apparatuses including source volumes and a destination storage apparatus to which the source volumes are migrated, the storage management system comprising:

- a processor;
- an input device;
- a display device; and
- a memory device,

the memory device holding:

- volume management information including information on owner apparatuses and characteristics of the source volumes;

- destination pool configuration management information created based on user specifications through the input device and including sizes of volumes to be allocated from storage device groups in the destination storage apparatus to destination pools; and

- volume migration configuration management information created based on user specifications through the input device and including information on relations between the source volumes and the destination pools,

wherein the processor determines source volume groups to which the source volumes belong based on the volume management information,

wherein the processor determines sizes of volumes to be allocated from the storage device groups to the destination pools based on the destination pool configuration management information,

wherein the processor determines sizes of volumes to be migrated from the source volume groups to the destination pools based on the volume migration configuration management information,

wherein the processor creates image data indicating information on the determined sizes of volumes to be allocated and the sizes of volumes to be migrated,

wherein the processor outputs the image data to the display device,

wherein the image displayed with the image data includes sections each indicating information on one of the destination pools,

wherein each of the sections is a column or a row consisting of a plurality of cells,

## 23

wherein each of the sections includes a first subsection and a second subsection,  
 wherein each cell in the first subsection indicates a size of volumes to be migrated from one of the source volume groups, and  
 wherein each cell of the second subsection indicates a size of volumes to be allocated from one of the storage device groups.

2. A storage management system according to claim 1, wherein the processor includes information on sizes of destination undetermined volumes of the source volume groups and sizes of unallocated volumes of the storage device groups in the image data, and  
 wherein the processor accepts specifications of migration of volumes from the source volumes groups to the destination pools and specifications of allocation of volumes from the storage device groups to the destination pools through user inputs to an image displayed with the image data.

3. A storage management system according to claim 1, wherein the sections are columns each consisting of a plurality of cells and are aligned in a row direction, wherein the columns each have a width proportional to a capacity of a corresponding destination pool, wherein, in each cell in the sections, a horizontal bar having a length proportional to a size of corresponding volumes represents the size of the corresponding volumes, wherein the horizontal bars in the cells of the first subsection are disposed not to be overlapped and to be continued in a row direction, and  
 wherein the horizontal bars in the cells of the second subsection are disposed not to be overlapped and to be continued in a row direction.

4. A storage management system according to claim 1, wherein the processor determines, in accordance with user specifications, the source volume groups to which the source volumes belong in such a manner that each of the source volume groups consists of source volumes owned by a same storage apparatus or a same host apparatus, based on the volume management information.

5. A storage management system according to claim 1, wherein the volume management information includes information on performance capabilities of the source volumes,  
 wherein the memory device holds performance class information defining performance classes for the source volumes, and  
 wherein the processor determines source volume groups to which the source volumes belong in such a manner that each of the source volume groups consists of source volumes belonging to the same performance class, based on the performance class information and the volume management information.

6. A storage management system according to claim 5, wherein the destination pool configuration management information includes information on performance capabilities of the destination pools,  
 wherein the processor determines increase or decrease in performance capability between before and after migration for each of the source volumes, based on the volume management information and the destination pool configuration management information, and  
 wherein the processor includes information indicating a result of the determination in the image data.

7. A storage management system according to claim 6, wherein, when the sizes of volumes to be allocated from the storage device groups to the destination pools are

## 24

changed, the processor updates the performance capabilities of the destination pools in the destination pool configuration management information in accordance with the changes,  
 wherein the processor redetermines increase or decrease in performance capability between before and after migration for each of the source volumes, based on the volume management information and the destination pool configuration management information, and  
 wherein the processor updates the image data to include a result of the redetermination and outputs the updated image data to the display device.

8. A storage management system according to claim 1, wherein the image provided by the image data includes cells corresponding to the storage device groups and cells corresponding to the source volume groups,  
 wherein the processor receives designation of a storage device group to allocate volumes and a destination pool to which the volumes are allocated by drag and drop of an image component from the cell corresponding to the storage device group to a cell corresponding to the destination pool, and  
 wherein the processor receives designation of a source volume group including source volumes to be migrated and a destination pool by drag and drop of an image component from the cell corresponding to the source volume group to a cell corresponding to the destination pool.

9. A storage management system according to claim 8, wherein, in response to the drop, the processor creates an image data for showing a list of unallocated volumes in the source volume group and outputs the image data to the display device.

10. A storage management system according to claim 1, wherein the volume management information includes information on owner apparatuses of the source volumes,  
 wherein the processor receives selection by the user of an owner apparatus of the source volumes, and  
 wherein the processor includes source volumes of a plurality of owner apparatuses other than the selected owner apparatus in one source volume group.

11. A storage management method performed by a storage management system for managing source storage apparatuses including source volumes and a destination storage apparatus to which the source volumes are migrated, the storage management system holding:  
 volume management information including information on owner apparatuses and characteristics of the source volumes;  
 destination pool configuration management information created based on user specifications through an input device and including sizes of volumes to be allocated from storage device groups in the destination storage apparatus to destination pools; and  
 volume migration configuration management information created based on user specifications through the input device and including information on relations between the source volumes and the destination pools,  
 the storage management method comprising:  
 determining source volume groups to which the source volumes belong based on the volume management information;

25

determining sizes of volumes to be allocated from the storage device groups to the destination pools based on the destination pool configuration management information;

determining sizes of volumes to be migrated from the source volume groups to the destination pools based on the volume migration configuration management information;

creating image data indicating information on the determined sizes of volumes to be allocated and the sizes of volumes to be migrated; and

outputting the image data to a display device,

wherein the image displayed with the image data includes sections each indicating information on one of the destination pools,

wherein each of the sections is a column or a row consisting of a plurality of cells,

wherein each of the sections includes a first subsection and a second subsection,

wherein each cell in the first subsection indicates a size of volumes to be migrated from one of the source volume groups, and

wherein each cell of the second subsection indicates a size of volumes to be allocated from one of the storage device groups.

\* \* \* \* \*

26